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PLANNING OF CROP AND WATER MANAGEMENT PRACTICES USING WEEKLY RAINFALL DATA

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CONTENTS

PREFACE

The adequacy of rainfall to meet the consumptive needs of crops and other consumptive and non-consumptive water needs is a basic requirement in a rainfed region. The considerable rainfall variability in space and time coupled with inadequate and uneven distribution of available water resources, particularly in drought prone areas result in frequent crop failures and shortage of fodder and drinking water. Estimates of the magnitude and duration of water deficit/ surplus are of vital importance for planning crop and water management practices in order to promote crop production both in irrigated and rainfed areas. An effort has been made in this study to evolve a strategy for contingency crop planning and water management practices to promote crop production in rainfed areas based on the magnitude and duration of water deficit/surplus.

Estimation of weekly rainfall at various probability levels were carried out to determine the rainfall deficit/surplus probabilities for crop planning. The rainfall data for Raichur and Koppal districts were analysed for estimating weekly rainfalls at different probability levels using statistical distribution. Rainfall deficit/surplus for different weeks was computed by comparing expected rainfall and consumptive use of all principal crops in the study area.

This report entitled 'Planning of Crop and Water Management Practices using Weekly Rainfall' has been prepared by Mr. A. V. Shetty, Scientist 'C', Dr. B. Soni, Scientist 'F' and Mr. Chandrakumar S., Research Assistant, Hard Rock Regional Centre, Belgaum.

Director

LIST OF FIGURES

LIST OF FIGURES

Figure No.	Title	Page No.

LIST OF TABLES

Table No.	Title	Page No.

Abstract

Weekly rainfall values have been estimated at various probability levels to determine rainfall deficit/surplus for planning of crop and water management practices and evaluating strategy to use alternative measures for irrigation and water management schemes in rainfed areas. To evolve a strategy for contingency crop planning and water management practices to promote crop production in rainfed areas, weekly probabilities, crop water requirements of all principal crops grown in the study areas were estimated and consistancy of weekly rainfall distribution were analysed.

Estimation of weekly rainfall at various probability levels were carried out to determine rainfall deficit/surplus for cop planning. The rainfall data about 22 years(1977-1999) of Raichur and Koppal was analysed for estimating the weekly probability of rainfall at 60, 70, 75, 80, and 90% levels using statistical distribution. Rainfall deficit/surplus for different weeks were computed by comparing expected rainfall and consumptive use of all principal crops grown in the study area. The strategy to adopt proper cropping pattern and alternative measures have been suggested for all principal crops grown in the study area.

1.0 INTRODUCTION

The adequacy of rainfall to meet the consumptive needs of crops and other consumptive and non-consumptive water needs is a basic requirement in any region. The considerable rainfall variability in space and time coupled with inadequate and uneven distribution of available water resources, particularly in drought prone areas, result in frequent crop failure and shortage of fodder and drinking water. Estimates of the magnitude and duration of water deficit/surplus are of vital importance for planning crop and water management practices in order to promote crop production both in irrigated and rainfed areas. Knowledge of rainfall and potential evapotranspiration (PET) is very useful to estimate the water availability periods for deciding the cropping pattern, water management and water harvesting practices and assessing the drought proneness of the area. Expected rainfall amount at various probability levels for different time periods, eg. monthly, weekly, etc. play an important role in estimating the water deficit/surplus at different periods.

Crop planning for an area depends upon number of factors, namely type of crop, cropping intensity, available water resources, climate, crop water requirements, method of irrigation, drainage, efficiency of the irrigation system, soil characteristics, topography, and socio-economic conditions, etc. However, in rainfed areas, it mainly depends upon the magnitude and distribution of rainfall both in space and time. Due to erratic behaviour of monsoon, generally there may be considerable variations of rainfall within the same month/week and from year to year. Thus, it is difficult to develop suitable predictive equations. Under such conditions, inspite of taking average rainfall values, models based on probability concept may serve more useful purpose.

1.1 Statistical Analysis

The random variability of hydrologic variables such as precipitation and stream flow has been recognised for centuries. The general field of hydrology was one of the first areas of science and engineering to use statistical concepts in an effort to analyse the natural phenomena. The use of statistics in hydrology provides information about various parameters and distribution of random variables as needed to design and operation of structures. These parameters and their distributions are estimated as approximations from the variable data because they can not be determined exactly.

Hydrologic data are mostly available as samples of limited sizes. Statistics enables the extraction of needed information from the available data and the characteristics of hydrologic random variables such as rainfall and runoff. Statistical estimates are numerical properties of samples and necessary in statistical modelling, for direct use in hydrology.

In any analysis of sample data, certain calculations are usually made to determine some of the basic inherent properties of the data. For instance, sample mean and variance are two statistics defining the most important characteristics of a given set of statistical data. In general, sample statistics provide the basic information about the variability of a given data set. The most useful sample statistics measure the following characteristics.

1. Central tendency of value around which all other values are clustered .
2. Symmetry or skewness of the frequency distribution and
3. Flatness of the frequency distribution.

Theses statistical properties are determined by sample statistics as mean, standard deviation, variance, coefficient of variation and skewness coefficient or symmetry. The sample mean measures the central tendency of a given data set. The standard deviation measures the dispersion of sample values around the mean. The skewness coefficient or coefficient of skewness measures the asymmetry of the frequency distribution of the data. The skewness coefficient has an important meaning since it gives indication of the symmetry of the distribution of the data. Symmetrical frequency distributions have very small or negligible sample skewness coefficient (C_s) while asymmetrical frequency distributions have either positive or negative coefficient. A small value of C_s often indicate that frequency distribution, of the sample may be approximated by the normal distribution function since $C_s = 0$ for this function.

The kurtosis coefficient measures the peakedness or the flatness of the frequency distribution near its centre. The positive value of excess coefficient indicates that a frequency distribution is more peaked around its centre than the normal distribution. The negative value of excess coefficient indicate that a given distribution is more flat around the its centre than the normal.

1.2 Probability Distribution

Probability is a constant characterising a given set of objects or incidents in a perticular period. The probability analysis of annual rainfall is useful to predict with reasonable accuracy of occurrence in different group intervals of annual rainfall. It is also possible to work out the exceedence probability of rainfall at different percentage levels.

One of the major problems encountered in hydrology is the estimation of probability levels from fairly short data. The probability can be conveniently estimated if the length of available data is more, however, the length of data available is generally very less. So the available short term data are used to fit probability distribution which is then used to extrapolate design events from the recorded events either graphically or by estimating the parameters of frequency distribution. Graphical method is having the advantage of simplicity and visual presentation but the main disadvantage is fitting of different curves by different users.

Determination of probability requires knowledge of the plotting positions. Chow (1964) has summarised the different plotting position formulae like California, Hazen, Weibull, Chegodayev, Blom and Turkey. The formula proposed by Weibull has been found to be theoretically suitable for plotting the annual maximum series. Hann and Shapiro (1967) concluded that Weibull formula provides estimates that are consistent with experience. Doorenbos and Pruitt (1977) presented the steps involved in determining estimates for rainfall probabilities. It was also suggested that in case of skewed distribution, square root or logarithm of the rainfall values may be attempted. For period with little or no rainfall, the plotting position is to be modified by the following equation;

$$G_a = p + (1-p)F_a \quad (1)$$

where G_a is the probability of occurrence and p is portion in which no rainfall occurred.

The daily annual rainfall series is divided into 52 weeks, starting from January 1. The last day of every year and last 2 days in the case of leap year are also accounted in the 52nd week. The Weibull formula is normally used to determine the rainfall probabilities at various levels e.g. 50, 60, 70, 80 and 90% for all weeks. Weibull formula can be mathematically expressed as:

$$F_a = (m/N+1)* 100 \quad (2)$$

Where N = total number of data items;

m = number of items arranged in descending order of magnitude; and

F_a = plotting position.

The following continuous distributions are normally used to fit the rainfall series.

Normal distribution - The normal distribution is one of the most important distributions in statistical hydrology. This is used to fit empirical distributions with symmetrical histograms or with skewness coefficient close to zero. The normal distribution enjoys unique position in the field of statistics due to its role in the central limit theorem. This theorem validates its use as an approximation to other distributions. The central limit theorem states that the distribution of sums of random variables from any distribution tends to a normal distribution as the number of terms in the sum increases.

Log normal distribution - Log normal distribution can be applied to a wide variety of hydrologic events especially in the cases in which the corresponding variable has a lower bound, the empirical frequency distribution is not symmetrical and the factors causing those events are independent and multiplicative. Chow (1964) provided a theoretical justification for the use of the log normal distribution. The causative factors for many hydrologic variables act multiplicatively rather than additively and so the logarithms of the peak flows, which are the product of these causative factors, follow the log normal distribution.

Pearson type III distribution - Pearson type III distribution is a three parameter distribution. This is also known as Gamma distribution with three parameters.

Log Pearson type III distribution - The log pearson Type III distribution has been widely used in hydrology, particularly for fitting the frequency distribution of flood data. The U.S. Water Resources Council recommended the use of Log Pearson type III distribution as an attempt to promote a uniform and consistent approach for flood frequency studies. As a result, the use of this distribution has become popular in the United States and has brought the attention of practicing engineers from Federal, State and local government as well as private organisations.

Extreme value distributions - Just as there is a family of Pearson type III distributions, each member being characterized by a value of γ there is also a family of EV distributions, each member of which is characterized by the value of a parameter denoted by k. The family can be divided into three classes, corresponding to different ranges of k values. The three classes are referred to as Fisher Tippett type 1, type 2 and type 3. They are also known as EV-1, EV-2 and EV-3 distributions. In practice, k value lie in the range-0.6 to + 0.6 For EV-1 distribution value of k is zero and for EV-2 and EV-3 - ve and + ve respectively.

1.3 Evapotranspiration and Potential Evapotranspiration

Water is essential for plant growth. It is needed for seeds to germinate, seedlings to emerge and for many plant growth functions. Water prevents the dehydration of plants, and provides the transport mechanism for plant nutrients and the products of photosynthesis. Crop yields under controlled irrigation are higher than rainfed conditions under similar climatic conditions. Because crop yields on irrigated lands are higher and more consistent than rainfed areas, irrigation plays an important role in stabilizing food and fibre production. The main objective of irrigation is to provide sufficient water to plants thereby preventing stress that may cause reduced yield or poor quality of harvest. The required timing and amount of irrigation (irrigation scheduling) is governed by the prevailing climatic conditions, type of crop and its stage of growth, soil moisture holding capacity, and the extent of root development.

In order to find out 'when' and 'how much' amount of irrigation is needed, it is necessary to know the consumption of water (evapotranspiration) by various crops in the field. One way to find 'when' is to observe crop indicators such as change of color or leaf angle, but this information may be too late to avoid reduction in crop yield and quality. The scientific approach to find 'when' and 'how much' would be to estimate water requirements of crops and then based on soil water balance predict 'when' and 'how much'. Researchers have investigated various ways of estimating crop water requirements by conducting experiments or developing empirical relations.

Only a small portion of the water absorbed by the root system of a plant remains in the plant tissue, virtually all is discharged to the atmosphere as vapour by a process called transpiration. This process constitutes an important phase of the hydrologic cycle since it is the principal mechanism by which the precipitation falling on land surface is returned to the atmosphere. For studying the water balance of a drainage basin, it is required to find out the evapotranspiration, a component which is combination of evaporation and transpiration. Transpiration is basically an evaporation process.

1.3.1 Estimation of Evapotranspiration

Evapotranspiration is a combined process by which water is transferred from earth surface to the atmosphere. It includes evaporation of liquid or soil water from soil and plant surfaces plus transpiration of liquid water through plant tissues expressed as the latent heat transfer per unit area or its equivalent depth of water per unit area (Jensen, 1983). Thornthwaite (1948) stipulated that soil moisture may have an effect upon the evapotranspiration and therefore suggested a term potential evapaotranspiration to define the transpiration that would occur in case of adequate supply available at all times. Jensen (1983) defined potential evapotranspiration as the rate at which water, if available, would be removed from the soil and plant surface expressed as the latent heat transfer per unit area or its equivalent depth of water per unit area. It has been found that evapotranspiration depends on the density of cover and its stage of development. Therefore, potential ET needs to be defined with reference to a particular surface cover. Some investigators in western USA have used the ET from a well-watered crop like alfalfa with 30-50 cm of top growth and at least 100 m of fetch, as representing potential ET (Jensen, 1974). Penman (1956) suggested that the original definition be modified to include the stipulation that the surface be fully covered by green vegetation. Van Bavel

(1966) defined potential ET as evapotranspiration that occurs when the vapour pressure at the evaporating surface is at the saturation point. Doorenbos and Pruitt (1977) defined the effect of climate on crop water requirements by the reference crop evapotranspiration (E_{To}) which they defined as 'the rate of evapotranspiration from an extensive surface of 8-15 cm tall, green grass cover of uniform height, actively growing, completely shading the ground and not short of water.

The crop evapotranspiration depends on several crop and environmental conditions such as climate, soil moisture, type of crop, stage of growth and the extent to which plants cover the soil. Hence, in order to have accurate estimates of crop E_T it is necessary to take these factors into account. If estimates of potential E_T for a reference crop are available, the estimates of E_T for specific crops can be made using the relation,

$$E_T = K_c \, Ep \quad (3)$$

where, K_c = crop coefficient

E_T = actual evapotranspiration

Ep = potential or reference evaporation

Experimentally developed crop coefficients reflect physiology of the crop, the degree of the crop cover, and the reference Ep. Factors affecting the values of crop coefficient (Kc) are mainly the crop characteristics, crop planting or sowing date, rate of crop development, length of growing season and climatic conditions. For experimental determination of crop coefficients, ideally, both crop E_T and reference Ep are measured concurrently. The crop coefficient is then calculated as the dimensionless ratio of the two measurements. Crop coefficients may either be based on alfalfa or green grass. Alfalfa is normally selected for reference Ep because it has relatively high E_T rates in arid areas where there is considerable advective sensible heat input from the air. The procedure for establishing alfalfa based crop coefficient is described in detail by Jensen (1974) and Jensen et al. (1971) . Doorenbos and Pruitt (1977) have described grass based crop coefficients in F.A.O. Irrigation and Drainage paper 24. They have divided the growth period of field and vegetable crops into four stages viz. i) initial stage, ii) crop development stage, iii) mid-season stage and iv) late season state. A procedure has been described to develop crop curve i.e. distribution of crop coefficients with time for various field and vegetable crops.

A lot of work has been done on water requirement of field crops in India. For principal crops like paddy, wheat, maize, bajra, barley, groundnut, mustard, linseed, cotton and sugarcane, the water requirement/irrigation requirement for different parts of the country have been suggested in literature.

1.3.2 Water requirement

A rational planning and management of water resources is not possible without comprehensive assessment of the need and availability of water. It includes the irrigation water requirement, domestic water requirement, industrial water requirement and water requirement for livestock.

1.3.2.1 Irrigation water requirement

The estimation of water requirement of crops is one of the basic needs for crop planning of any irrigation project and rainfed areas. Water requirement may be defined as the quantity of water, regardless of its source, required by a crop or diversified pattern of crops in a given period of time for its normal growth under field conditions at a place.

The irrigation water requirement for a crop depends upon the irrigation need of crop, the area occupied by the crop and losses in the water distribution system. Irrigation water requirement, IR is given by

$$IR = WR - ER + Losses \tag{4}$$

where,

WR= Crop water requirement, and

ER= Effective rainfall.

1.3.2.2 Crop water requirement

Crop water requirement may be defined as the quantity of water, regardless of its source, required by a crop for its normal growth under field conditions at a place. Crop water requirement may be formulated as follows:

WR = Evapotranspiration + application losses + special needs

Application losses include the loss of water during water application. These losses are unavoidable losses. Special needs include water required for land preparation, transplanting, leaching, etc.

1.3.2.3 Effective rainfall

Some part of the total water requirements of crop may be met by rainfall. Effective rainfall is that part of rain which enters the root zone and remains there as soil moisture. Crop water needs can be fully or partly met by rainfall. A part of total rainfall may be lost by surface runoff, deep percolation and evaporation. In case of rainfall of high intensity only a part of the rain enters and is stored in the root zone and the quantity of effective rain is low. Frequent light intensity rains on an area are more effective for meeting the crop water requirement. With dry soil surface and little or no vegetative cover, rainfall upto 8 mm/day may be lost totally by evaporation. For rains of 25 mm to 30 mm per day with low percentage of vegetative cover, only 60 percent of it is contributes as effective rainfall.

A number of empirical formulae can be used for estimating the effective rainfall. The formula developed under a given set of conditions may not be applicable for different conditions elsewhere. However, in this study, consumptive use/precipitation ratio method developed by soil conservation service of USDA (1969) has been adopted. In this method, monthly effective rainfall is related to monthly consumptive use as presented in table 1. The soil water storage capacity in the crop root zone at the time of irrigation is assumed to be equal to 75 mm.

1.4 Objective of the Study

The main objective of the study is to evolve a strategy for contingency crop planning and water management practices to promote crop production in rainfed areas based on the magnitude and duration water deficit and surplus.

The study involves the following steps:

1. Sample statistical analysis

Table 1: Normal Monthly Effective Rainfall as Related to Normal Monthly Rainfall and Average Monthly Consumptive Use

Normal Monthly Rainfall (mm)	Average Monthly Consumptive Use in mm													
	25	50	75	100	125	150	175	200	225	250	275	300	325	350
	Normal Monthly Effective Rainfall (mm)													
25	15	17	18	18	19	20	21	22	25	25	25	25	25	25
50	25	33	35	36	37	40	41	44	48	50	50	50	50	50
75		47	51	54	56	58	61	65	69	74	75	75	75	75
100		50	65	69	73	75	79	83	88	95	100	100	100	100
125			75	83	89	91	96	102	108	116	123	125	125	125
150				97	104	106	113	120	127	136	144	150	150	150
175				100	117	120	128	136	143	154	166	172	175	175
200					125	131	140	148	158	169	184	191	197	200
225						142	152	162	175	189	200	210	220	225
250						148	164	175	192	206	216	226	236	245
275						150	173	188	205	223	233	242	255	265
300							175	195	215	235	246	258	273	288
325								199	220	242	258	275	290	304
350								200	224	245	265	285	303	320
375									225	248	270	292	310	328
400										250	273	296	317	335
425											275	298	320	340
450												300	322	343
475													324	346
500													325	349
525														350

2. Estimation of weekly probability of exceedence at 50, 60, 70, 75, 80 and 90% levels for the study area using suitable statistical distribution.
3. Identification of principal crops swon in the area and estimation of consumptive use of each crop different stages of growth.
4. The adequacy of rainfall to meet the consumptive use of crops is worked out in accordance with probability of exceedence level and effective rainfall for the crop.
5. Evolve a crop contingency plan and management strategy for the study area with crop types and rainfall probabilities.

2.0 STUDY AREA

In the present study, two districts namely, Raichur and Koppal were selected. However, until recent past both the districts were together called as Raichur district. Undivided, Raichur district was between latitude 75° 50' and 77°40', longitude 15° 10' 16° 32' and a geographical area 13,88338 Hectares. The whole district was encompassed by Thungabhadra and Krishna rivers acting as a doab. About half of geographical area of the district was contributing catchment for Thungabhadra river and rest half contributing to the Krishna river. The divider of Thungabhadra and Krishna basins lies within the district. Out of nine taluks in the district, five taluks namely Gangavathi, Koppal, Kustagi, Sindhanur and Yalberga comes under newly constituted district Koppal district. Koppal, Yelberga and Kustagi taluks are considered to be rainfed areas. Raichur, Deodurga, Manvi and Lingasugur taluks are in the divided Raichur district. Except Lingasugur taluk, all other taluks in newly constituted Raichur district considered are as rainfed areas. Both the districts come under north-eastern and north dry zones of Karnataka state. The location map of the study area presented in the figure 1.

3. 0 METHODOLOGY

The basic aim of the study to find out the adequacy of rainfall to meet the consumptive needs of principal crops grown in the study area. The considerable rainfall variability in space and time coupled with inadequate and uneven distribution of available water resources in raifed areas. Therefore statistical analysis has been carried out to find out the distribution of rainfall in space and time. Estimate of the magnitude and duration of water deficit and surplus are of vital importance for planning crop and water management practices to promote crop production both in irrigated and rainfed areas. The estimation of probability exceedence at different percentage levels and consumptive use of crops in the study area has been carried out to estimate the magnitude and duration of water deficit and surplus.

3.1 Sample Statistics

Two raingauge stations namly Raichur and Devadurg for Raichur district and three rain gauges namely Koppal, Yelburga and Kustagi for Koppal taluk were used for the statistical anlysis of weekly rainfall over the selected study area. Daily rainfall data 22 years (1977-1998) have been analysed for mean, standard deviation, variance, coefficient of variability, and coefficient of asymmetry. The statistical results have been presented in the tables 2 and 3.

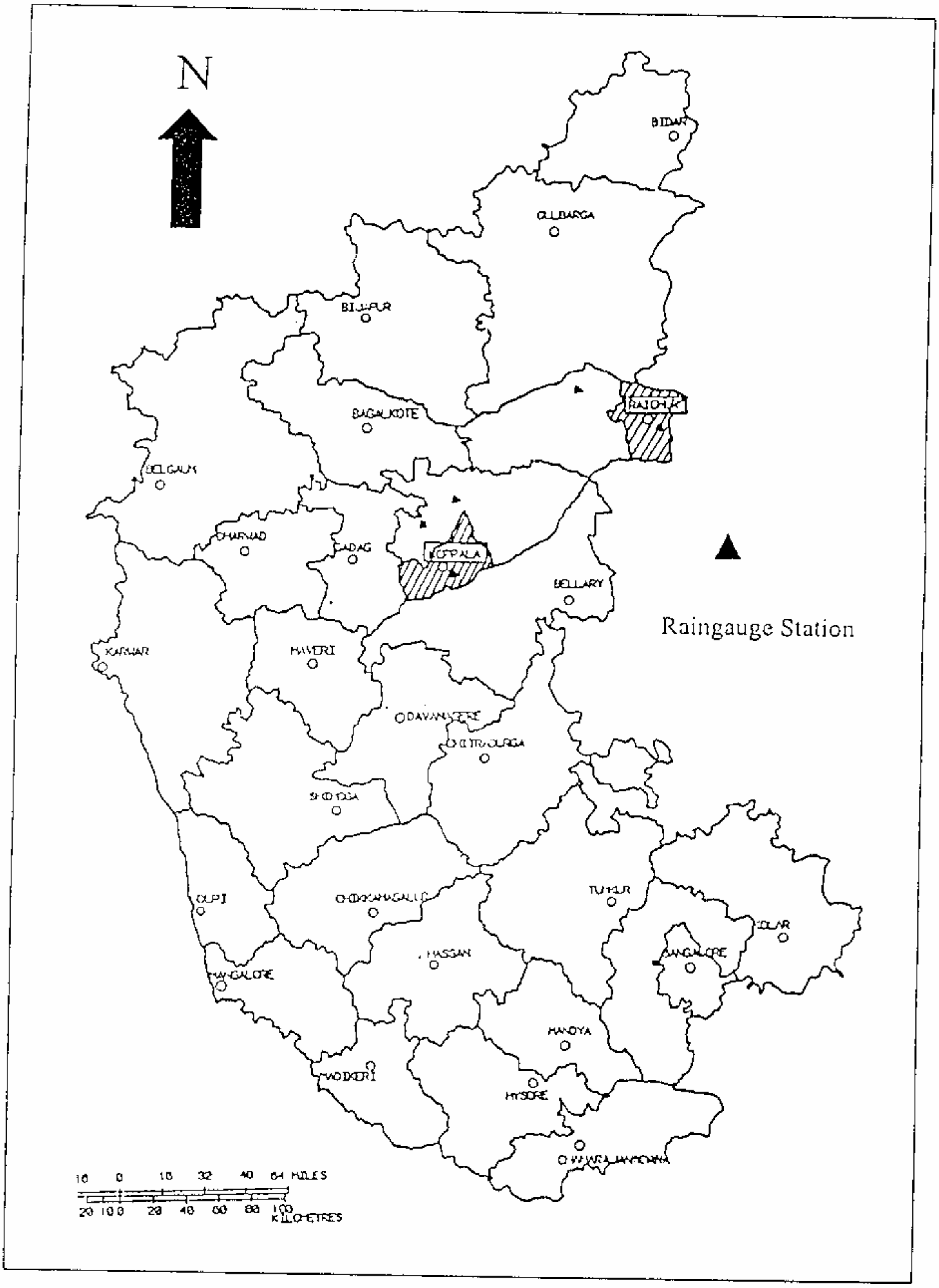

FIGURE 1. LOCATION MAP OFTHE STUDY AREA

Table 2: Sample Statistics of Weekly Rainfall for Raichur

Beginning Date	Week No.	Mean Rainfall	Variance	Standard Deviation	Coefficient of Variability	Coefficient of Assymetry
Jan-01	1	0.26	-	-	-	-
8	2	0.63	-	-	-	-
15	3	1.6	-	-	-	-
22	4	0.54	-	-	-	-
29	5	0	-	-	-	-
Feb-05	6	0.99	-	-	-	-
12	7	1.07	-	-	-	-
19	8	0.19	-	-	-	-
26	9	0.24	-	-	-	-
Mar-05	10	1.11	-	-	-	-
12	11	0.48	-	-	-	-
19	12	1.07	5.41	2.33	2.27	4.55
26	13	2.42	21.28	4.61	1.99	3.98
Apr-02	14	3.61	52.72	7.26	2.11	4.21
9	15	2.23	26.41	5.14	2.4	4.79
16	16	2.95	56.08	7.49	2.66	5.33
23	17	8.86	205.17	14.32	1.69	3.39
30	18	1.83	8.29	2.88	1.39	2.79
May-07	19	10.86	322.86	17.96	1.68	3.35
14	20	8.85	168.43	12.97	1.52	3.04
21	21	10.89	351.61	18.75	1.8	3.6
28	22	9.01	155.79	12.48	1.45	2.9
Jun-04	23	14.86	212.58	14.58	1.01	2.01
11	24	32.11	1840.14	42.89	1.37	2.75
18	25	25.34	641.41	25.32	0.98	1.96
25	26	22.22	841.09	29	1.33	2.66
Jul-02	27	26.19	791.04	28.16	1.098	2.19
9	28	30.29	951.04	30.83	1.06	2.12
16	29	32.82	1097.9	33.14	0.97	1.95
23	30	38.7	1031.65	32.12	0.88	1.77
30	31	27.4	501.96	22.41	0.795	1.59
Aug-06	32	42.09	1891.2	43.49	1.02	2.05
13	33	38.39	1326.06	36.42	0.97	1.95
20	34	24.84	1099.35	33.16	1.16	2.32
27	35	32.78	1718.01	41.45	1.31	2.62
Sep-03	36	17.04	586.78	24.22	1.19	2.39
10	37	37.05	2243.92	47.37	1.22	2.45
17	38	40.96	1182.65	34.39	0.84	1.67
24	39	41.89	2087.49	45.68	1.05	2.1
Oct-01	40	39.15	3004.64	54.82	1.43	2.86
8	41	20.3	1268.54	35.62	1.56	3.12
15	42	13.33	1997.06	44.69	2.14	4.28
22	43	8.57	108.39	10.4	1.66	3.22
29	44	10.9	245.71	15.68	1.46	2.91
Nov-05	45	9.52	182.9	13.52	1.46	2.92
12	46	5.35	119.23	10.92	2.12	4.24
19	47	0.42	1.21	1.1	2.73	5.46
26	48	3.19	75.421	8.68	2.86	5.71
Dec-02	49	2.78	48.33	6.95	2.62	5.25
9	50	8.62	360.26	18.98	3.14	6.28
16	51	2.23	13.43	3.66	1.69	3.37
23	52	7.89	194.16	13.93	1.89	3.79

Table 3: Sample Statistics of Weekly Rainfall for Koppal						
Beginning Date	Week No.	Mean Rainfall	Variance	Standard Deviation	Coefficient of Variability	Coefficient of Assymetry
Jan-01	1	0.06	-	-	-	-
8	2	0	-	-	-	-
15	3	1.49	-	-	-	-
22	4	0	-	-	-	-
29	5	0	-	-	-	-
Feb-05	6	0.14	-	-	-	-
12	7	0.2	-	-	-	-
19	8	0	-	-	-	-
26	9	0.48	-	-	-	-
Mar-05	10	0.37	-	-	-	-
12	11	1.09	-	-	-	-
19	12	0.23	-	-	-	-
26	13	1.24	-	-	-	-
Apr-02	14	2.89	39.24	6.26	2.27	4.54
9	15	3.59	56.46	7.51	2.19	4.38
16	16	5.56	73.27	8.56	1.61	3.22
23	17	8.39	115.07	10.72	1.34	2.68
30	18	3.68	30.89	5.56	1.35	2.7
May-07	19	7.25	64.01	8	1.07	2.14
14	20	12.9	121.94	11.04	0.88	1.76
21	21	13.89	471.09	21.71	1.57	3.14
28	22	16.01	188.95	13.75	0.89	1.79
Jun-04	23	23.24	899.44	29.99	1.34	2.68
11	24	25.75	779.67	27.92	1.14	2.27
18	25	9.01	137.22	11.71	1.08	2.16
25	26	15.29	395.58	19.89	1.3	2.61
Jul-02	27	10.02	67.65	8.23	0.81	1.62
9	28	16.67	514.16	22.68	1.39	2.79
16	29	12.58	122.09	11.049	0.84	1.67
23	30	20.83	488.79	22.11	1.02	2.04
30	31	18.85	381.58	19.53	1.04	2.08
Aug-06	32	17.98	475.41	21.8	1.12	2.24
13	33	13	120.84	10.99	0.83	1.66
20	34	14.1	246.06	15.69	1.07	2.13
27	35	30.28	1656.63	40.7	1.38	2.76
Sep-03	36	21.64	933.48	30.55	1.33	2.67
10	37	32.58	1596.53	39.96	1.17	2.33
17	38	42.33	2090.79	45.73	1.08	2.16
24	39	37.95	858.85	29.31	0.72	1.44
Oct-01	40	39.08	1258.01	35.47	0.915	1.83
8	41	22.13	1722.44	41.5	1.75	3.49
15	42	14.67	592.31	24.34	1.44	2.87
22	43	16.41	560.78	23.68	1.51	3.02
29	44	9.24	250.62	15.83	1.77	3.56
Nov-05	45	10.06	385.96	19.65	1.96	3.92
12	46	15.95	1508.12	38.84	2.52	5.05
19	47	3.31	78.83	8.88	2.81	5.62
26	48	1.7	-	-	-	-
Dec-02	49	4.91	-	-	-	-
9	50	4.35	-	-	-	-
16	51	0.69	-	-	-	-
23	52	2.06	-	-	-	-

3.2 Probability Analysis

Weekly rainfall data for 22 years (1977-1998) for both Raichur and Koppal districts have been analysed for estimating expected rainfall at different probability levels. For planning crop and water management practices water deficit/surplus using Gauss, Lognormal, Gumble Pearson Type -III and Weibul formula. Lognormal and Weibul have been found to give better consistancy in estimating the probability levels. In the present study, Weibul formula has been used to estimate the probability levels. The daily annual rainfall series was divided into 52 weeks, starting from January 1. The last day of every year and last 2 days in case of leap year were also accounted in the 52[nd] week. The Weibul formula was used to determine the rainfall probabilities at various levels, e.g. 50, 60, 70, 80 and 90% for all weeks. Different steps involved in this analysis are,

a. Tabulation of weekly data

b. Arrangement of weekly data in descending order.

Thus if $x_1, x_2, x_3, \ldots x_n$ are the original unordered observations then the ordered observations to be denoted $x_1, x_2, x_3, \ldots x_n$ are such that $x_1, >> x_2, >> x_3, >>, \ldots x_n$ assigning serial numbers, m, to weekly data thus m=1 for the largest magnitude and every successive data in the descending order is assigned as 2, 3, 4,…,m.

c. determination of plotting position, Fa by use of equation (2).

d. For periods with little or no rainfall use equation (1)

e. Plot values of F_a or G_a on X- axis and the rainfall sequences on Y- axis on arithmetic probability paper.

f. Determination of magnitude of rainfall for 50, 60, 70, 80, and 90% probabilities.

Rainfall at 50, 60, 70, 80and 90% probability levels for all the weeks have been given in tables 4 and 5 for study areas.

Different weightages were assigned to normal distribution, log normal distribution and square root distribution to determine the mixed distribution. Based on chi-square test, it was found that lognormal distribution fits better as compared to normal and square root distributions. Rainfall for different probabilities for all weeks was determined from probability graphs and corresponding values are worked out. As a typical example sample plots have been presented in figures 2 to 5 to illustrate the results for 25^{ht} and 32nd weeks of Raichur and for 22nd and 37th week of Koppal. Tables 6 and 7 give the fitted distribution and probability of exceedance equation for both Raichur and Koppal Taluk.

3.3 Estimation of Consumptive Use

The consumptive use a crop depends upon the type and stage of growth, soil moisture, soil type and environmental conditions such as climate. Factors affecting the crop coefficient (K) are mainly the crop characteristics, crop planting and sowing date, rate of crop development, length of growing season and climatic conditions. For the present study, crop coefficients were taken as given by Water Management Division, Department of Agriculture, Irrigation, Govt. of India, 1971 (table 8).

Monthly pan evaporation data of Kustagi for Koppal district and Yermuras for Raichur district from 1990 to 1998 were used to estimate the monthly potential evapotranspiration of principal crops grown in the study area. Principal crops and crop calendar is given in the table 9. The potential evapotranspiration of each principal crops

Table 4: Rainfall at Different Probability Levels (Raichur)

Beginning Date	Week No.	Mean Rainfall	Rainfall in mm 50%	60%	70%	80%	90%
Jan-01	1	0.25	0	0	0	0	0
8	2	0.60	0	0	0	0	0
15	3	1.53	0	0	0	0	0
22	4	0.51	0	0	0	0	0
29	5	0.00	0	0	0	0	0
Feb-05	6	0.94	0	0	0	0	0
12	7	1.02	0	0	0	0	0
19	8	0.18	0	0	0	0	0
26	9	0.23	0	0	0	0	0
Mar-05	10	1.06	0	0	0	0	0
12	11	0.45	0	0	0	0	0
19	12	1.02	0.41	0.32	0.22	0.13	0.07
26	13	2.31	1.04	0.81	0.59	0.36	0.2
Apr-02	14	3.45	1.48	1.15	0.83	0.5	0.28
9	15	2.13	0.82	0.63	0.45	0.26	0.14
16	16	2.81	0.99	0.76	0.52	0.29	0.15
23	17	8.62	4.3	3.41	2.51	1.62	0.97
30	18	2.06	1.2	0.97	0.73	0.5	0.32
May-07	19	10.72	5.49	4.35	3.22	2.08	1.25
14	20	8.55	4.7	3.76	2.81	1.87	1.16
21	21	10.40	5.05	3.98	2.91	1.84	1.08
28	22	8.60	4.88	3.92	2.95	1.99	1.25
Jun-04	23	14.50	10.23	8.51	6.78	5.06	3.5
11	24	31.15	18.3	14.76	11.23	7.69	4.88
18	25	25.79	18.42	15.36	12.29	9.23	6.43
25	26	21.80	13.1	10.6	8.1	5.6	3.59
Jul-02	27	25.60	17.24	14.21	11.19	8.16	5.51
9	28	29.13	20	16.55	13.1	9.65	6.58
16	29	33.91	24.26	20.24	16.21	12.19	8.49
23	30	36.23	27.11	22.84	18.56	14.29	10.21
30	31	28.18	22.06	18.79	15.52	12.25	9
Aug-06	32	42.49	29.69	24.65	19.61	14.57	10.03
13	33	37.38	26.77	22.34	17.9	13.47	9.39
20	34	28.55	18.62	15.27	11.91	8.56	5.7
27	35	31.65	19.2	15.56	11.93	8.29	5.33
Sep-03	36	20.24	12.97	10.6	8.24	5.87	3.87
10	37	38.56	24.34	19.85	15.36	10.87	7.12
17	38	41.14	31.56	26.74	21.93	17.11	12.41
24	39	43.43	29.93	24.78	19.63	14.48	9.9
Oct-01	40	38.23	21.89	17.59	13.3	9	5.65
8	41	22.83	12.32	9.83	7.33	4.84	2.96
15	42	20.90	8.85	6.88	4.91	2.94	1.65
22	43	6.27	3.23	2.56	1.9	1.23	0.74
29	44	10.78	6.1	4.9	3.69	2.49	1.56
Nov-05	45	9.28	5.25	4.21	3.18	2.14	1.34
12	46	5.15	2.2	1.71	1.22	0.73	0.41
19	47	0.40	0.14	0.11	0.07	0.04	0.02
26	48	3.04	1	0.76	0.53	0.29	0.15
Dec-02	49	2.65	0.94	0.72	0.5	0.28	0.15
9	50	6.32	1.84	1.39	0.95	0.5	0.25
16	51	2.13	1.11	0.88	0.65	0.42	0.25
23	52	7.34	3.42	2.68	1.95	1.21	0.7

Table 5: Rainfall at Different Probability Levels (Koppal)

Beginning Date	Week No.	Mean Rainfall	Rainfall in mm 50%	60%	70%	80%	90%
Jan-01	1	0.06	-	-	-	-	-
8	2	0.00	-	-	-	-	-
15	3	1.42	-	-	-	-	-
22	4	0.00	-	-	-	-	-
29	5	0.00	-	-	-	-	-
Feb-05	6	0.13	-	-	-	-	-
12	7	0.20	-	-	-	-	-
19	8	0.00	-	-	-	-	-
26	9	0.46	-	-	-	-	-
Mar-05	10	0.35	-	-	-	-	-
12	11	1.04	-	-	-	-	-
19	12	0.22	-	-	-	-	-
26	13	1.18	-	-	-	-	-
Apr-02	14	2.76	1.11	0.86	0.61	0.36	0.2
9	15	3.43	1.42	1.1	0.79	0.47	0.26
16	16	5.31	2.8	2.23	1.65	1.08	0.66
23	17	8.01	4.79	3.87	2.96	2.04	1.31
30	18	4.13	2.44	1.97	1.51	1.04	0.66
May-07	19	7.48	5.11	4.22	3.34	2.45	1.67
14	20	12.53	9.4	7.92	6.45	4.97	3.56
21	21	13.84	7.44	5.93	4.43	2.92	1.78
28	22	15.28	11.37	9.56	7.76	5.95	4.24
Jun-04	23	22.36	13.36	10.8	8.25	5.69	3.64
11	24	24.58	16.24	13.34	10.45	7.55	5.06
18	25	10.83	7.36	6.08	4.79	3.51	2.38
25	26	15.27	9.3	7.54	5.79	4.03	2.59
Jul-02	27	10.19	7.93	6.74	5.56	4.37	3.2
9	28	16.25	9.47	7.63	5.79	3.95	2.5
16	29	13.22	10.14	8.59	7.05	5.5	3.99
23	30	21.71	15.21	12.63	10.06	7.48	5.16
30	31	18.72	12.95	10.73	8.51	6.29	4.31
Aug-06	32	19.50	13	10.7	8.4	6.1	4.1
13	33	13.23	10.17	8.62	7.08	5.53	4.02
20	34	14.72	10.07	8.33	6.58	4.84	3.3
27	35	29.52	17.34	13.99	10.63	7.28	4.62
Sep-03	36	22.90	13.73	11.11	8.49	5.87	3.76
10	37	34.29	22.33	18.3	14.28	10.25	6.81
17	38	41.46	28.76	23.91	19.7	13.73	9.31
24	39	40.68	33.01	28.39	23.78	19.16	14.41
Oct-01	40	38.75	28.58	24	19.41	14.83	10.51
8	41	23.72	11.77	9.3	6.82	4.35	2.58
15	42	16.95	9.69	7.79	5.88	3.98	2.5
22	43	15.67	8.64	6.91	5.18	3.45	2.14
29	44	8.90	4.36	3.44	2.52	1.6	0.94
Nov-05	45	10.01	4.55	3.56	2.57	1.58	0.91
12	46	15.38	5.67	4.36	3.04	1.73	0.93
19	47	3.16	1.06	0.81	0.56	0.31	0.16
26	48	1.62	-	-	-	-	-
Dec-02	49	4.69	-	-	-	-	-
9	50	4.15	-	-	-	-	-
16	51	0.66	-	-	-	-	-
23	52	1.97	-	-	-	-	-

Figure 2: Ranking and Weighed Transformation Distribution Curve
Raichur - Week No. 25

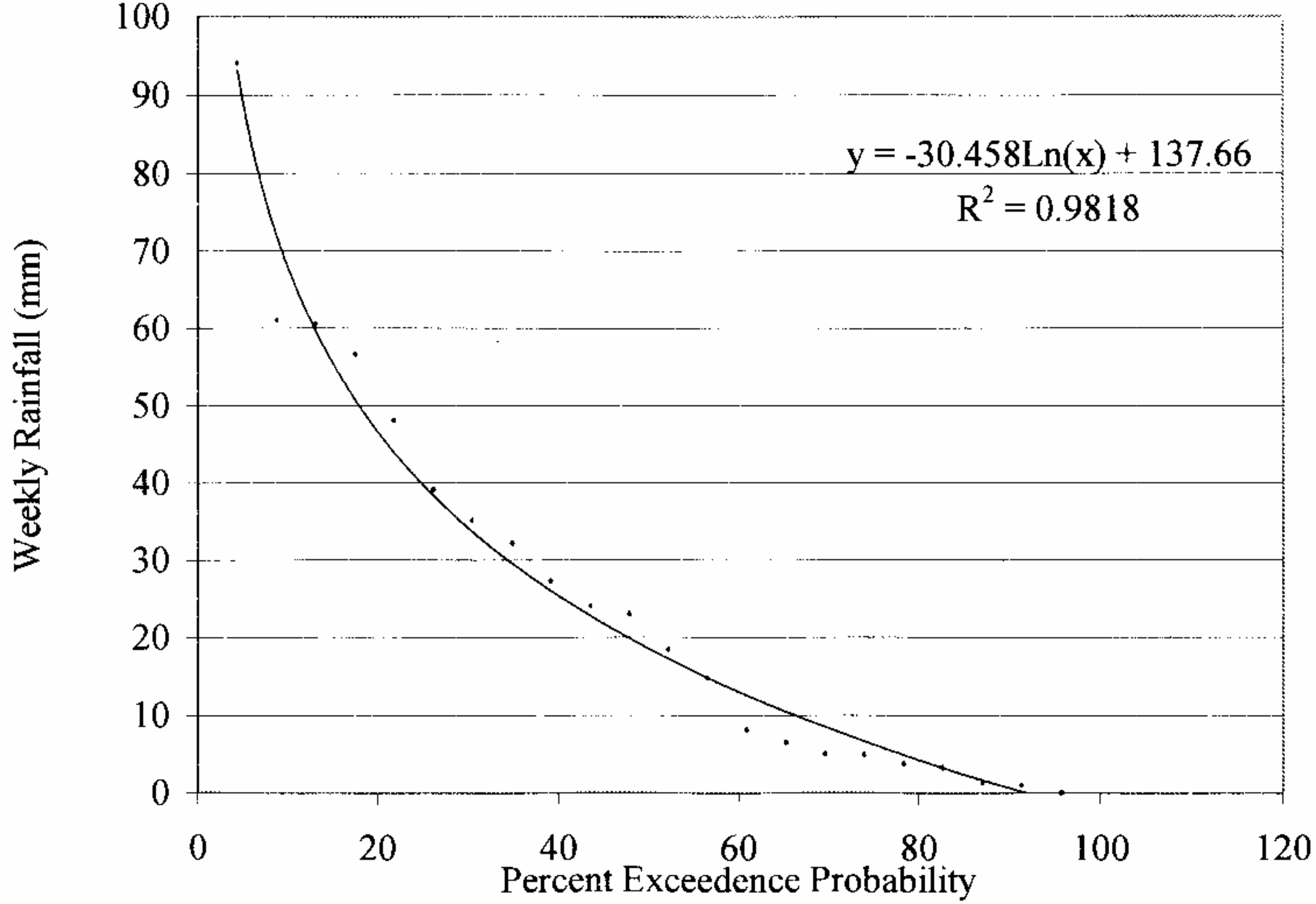

Figure 3: Ranking and Weighed Transformation Distribution Curve
Raichur - Week : 32

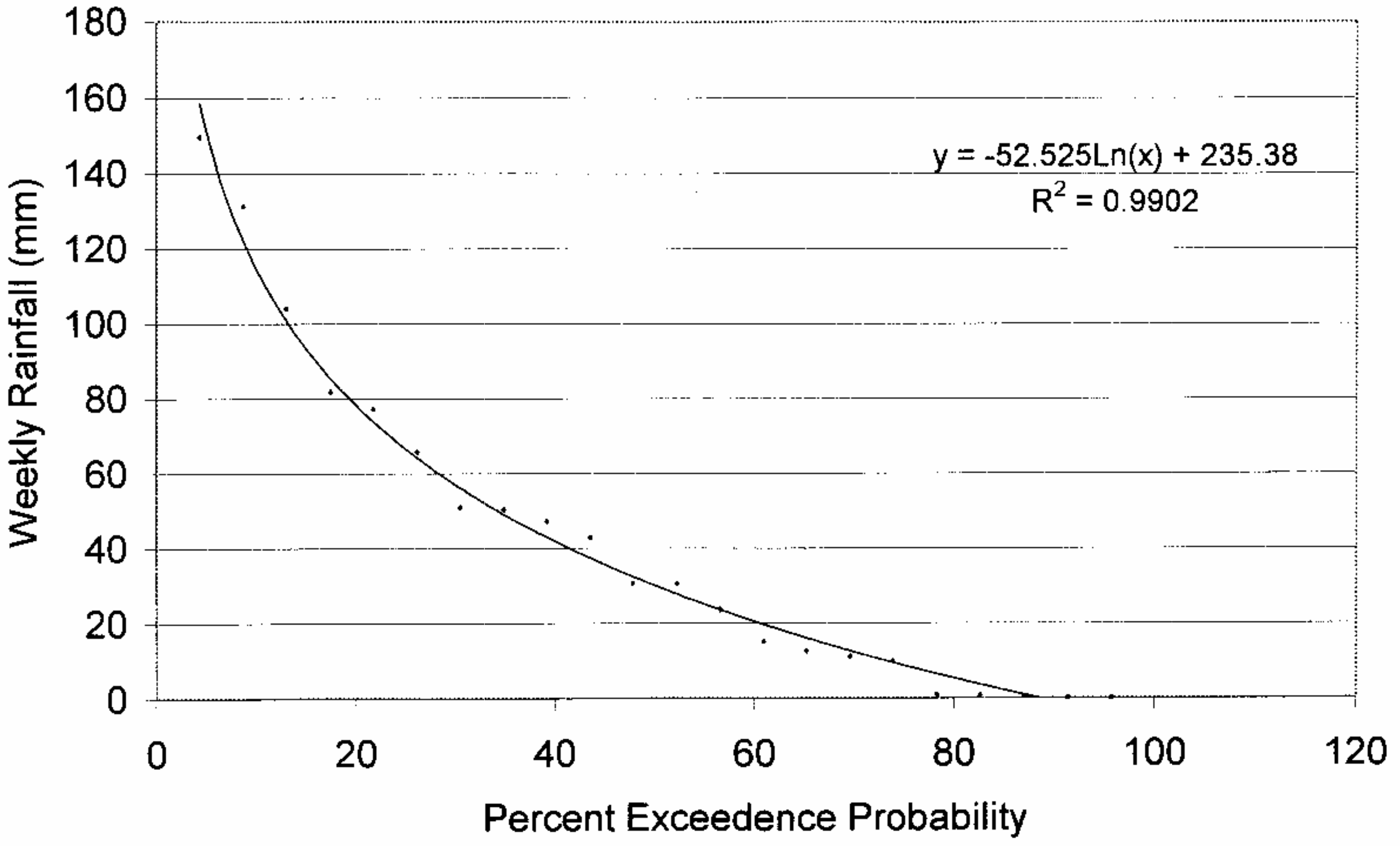

Figure 4: Ranking and Weighed Transformation Distribution Curve
Koppal- Week No. 22

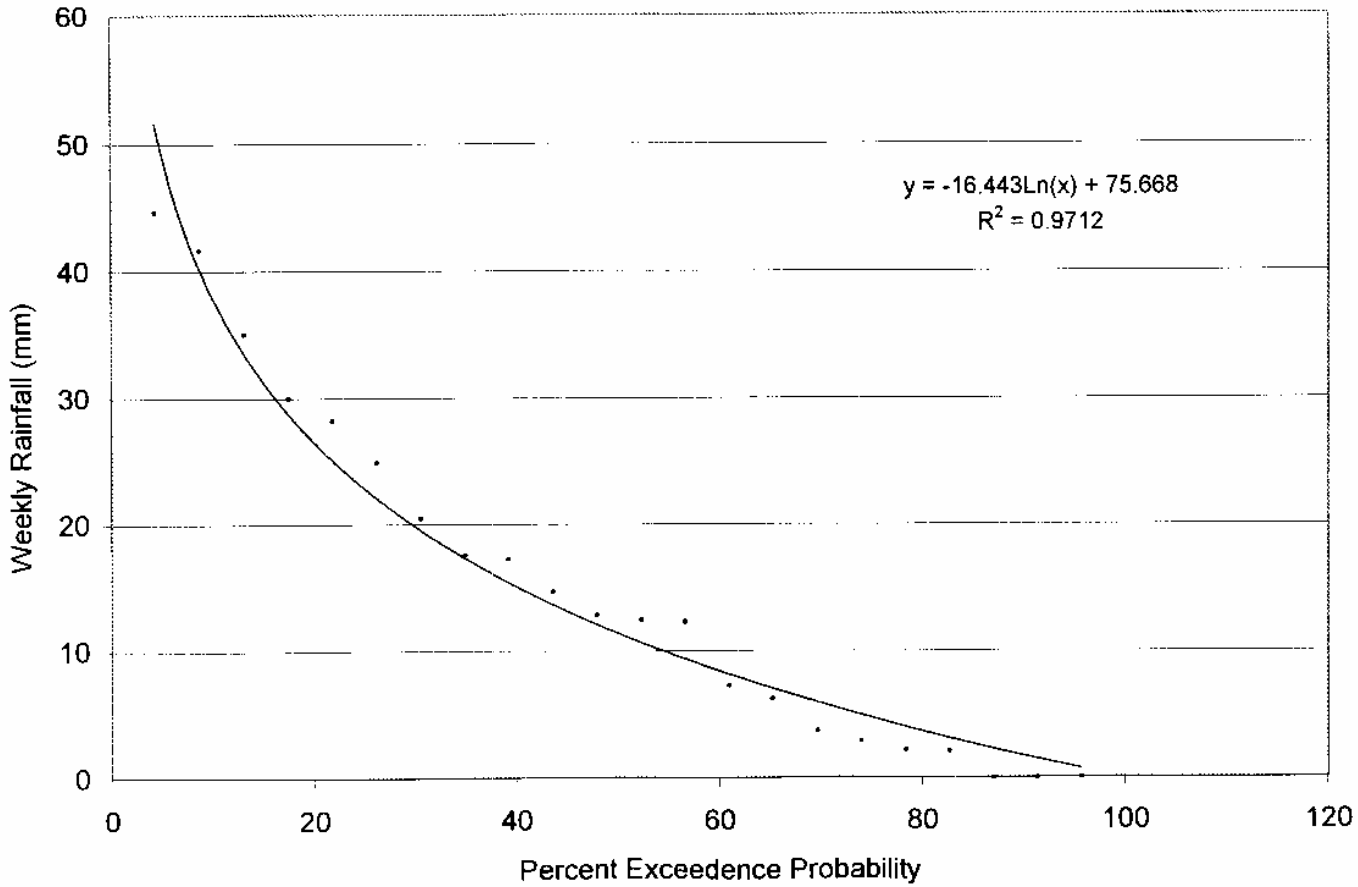

Figure 5: Ranking and Weighed Transformation Distribution Curve
Koppal- Week No. 37

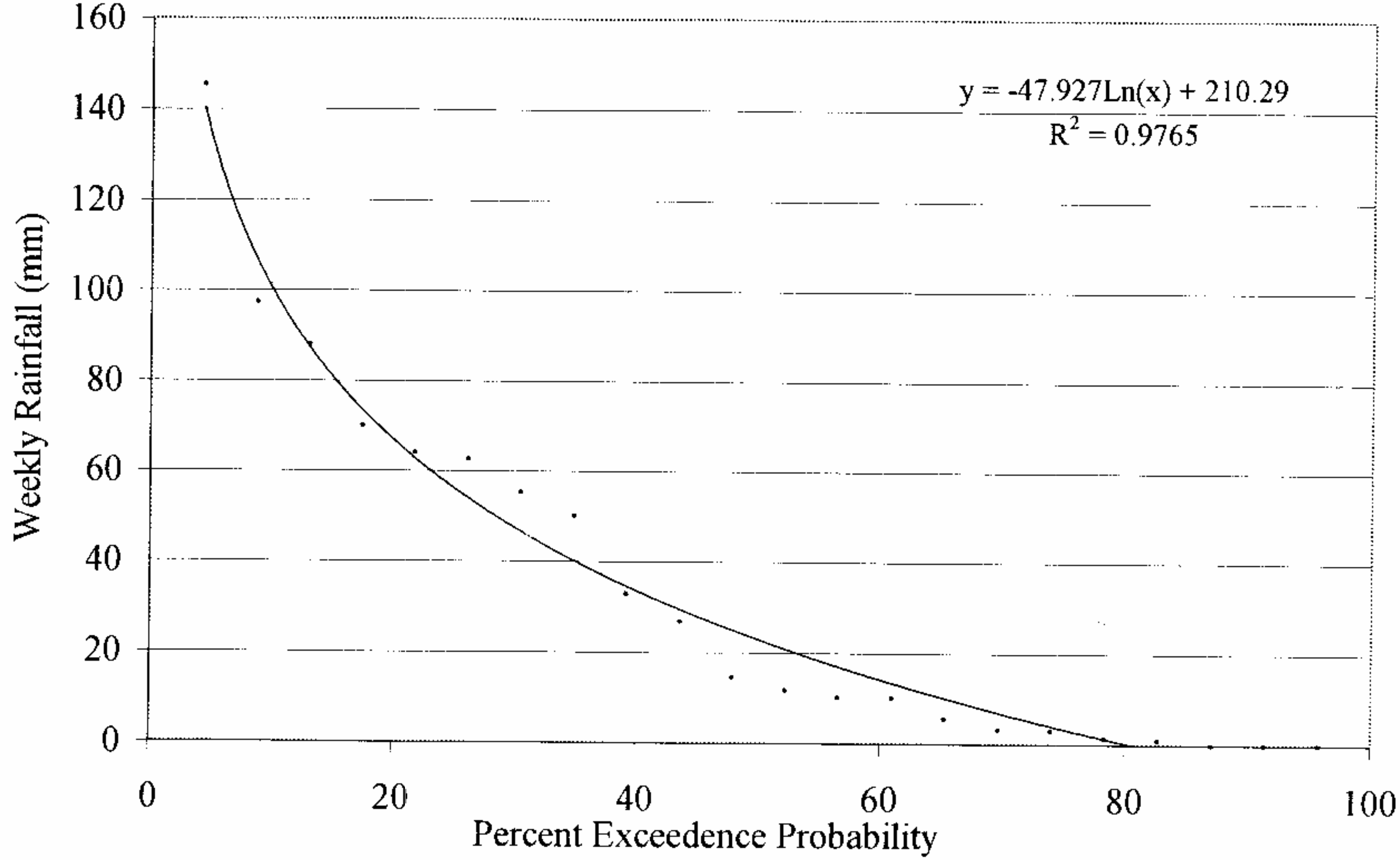

Table 6: Ranking and Weighed Transformation Distribution Equation (Raichur)

Sl.No.	Week No.	Fitted Equation	R^2
1	12	y = -2.3954Ln(x) + 9.8194	0.7199
2	13	y = -5.1409Ln(x) + 21.193	0.8432
3	14	y = -7.9945Ln(x) + 32.806	0.8228
4	15	y = -5.3395Ln(x) + 21.751	0.7328
5	16	y = -7.3014Ln(x) + 29.624	0.6452
6	17	y = -16.363Ln(x) + 68.545	0.8857
7	18	y = -3.3154Ln(x) + 14.234	0.8992
8	19	y = -20.809Ln(x) + 86.863	0.8982
9	20	y = -14.529Ln(x) + 61.903	0.8507
10	21	y = -20.738Ln(x) + 86.559	0.8302
11	22	y = -14.661Ln(x) + 62.44	0.9364
12	23	y = -17.588Ln(x) + 79.089	0.9877
13	24	y = -48.158Ln(x) + 208	0.8554
14	25	y = -30.458Ln(x) + 137.66	0.9818
15	26	y = -34.05Ln(x) + 146.84	0.9356
16	27	y = -33.402Ln(x) + 148.27	0.9573
17	28	y = -36.145Ln(x) + 161.91	0.9347
18	29	y = -39.23Ln(x) + 177.98	0.9515
19	30	y = -36.913Ln(x) + 169.97	0.8528
20	31	y = -25.613Ln(x) + 122.24	0.8871
21	32	y = -52.525Ln(x) + 235.38	0.9902
22	33	y = -43.6Ln(x) + 197.48	0.973
23	34	y = -39.124Ln(x) + 172.22	0.945
24	35	y = -48.524Ln(x) + 209.75	0.9271
25	36	y = -29.144Ln(x) + 127.26	0.9825
26	37	y = -55.893Ln(x) + 243.81	0.945
27	38	y = -41.354Ln(x) + 192.95	0.9775
28	39	y = -53.498Ln(x) + 239.89	0.9306
29	40	y = -63.017Ln(x) + 268.3	0.9213
30	41	y = -41.803Ln(x) + 176.34	0.935
31	42	y = -47.641Ln(x) + 195.85	0.7714
32	43	y = -12.08Ln(x) + 50.627	0.9137
33	44	y = -18.523Ln(x) + 78.796	0.9486
34	45	y = -15.998Ln(x) + 68.029	0.9497
35	46	y = -11.736Ln(x) + 48.254	0.7841
36	47	y = -1.0949Ln(x) + 4.4232	0.6724
37	48	y = -8.2937Ln(x) + 33.498	0.619
38	49	y = -7.0528Ln(x) + 28.55	0.6985
39	50	y = -17.526Ln(x) + 70.354	0.5777
40	51	y = -4.2536Ln(x) + 17.791	0.9147
41	52	y = -14.368Ln(x) + 60.102	0.7217

Table 7: Ranking and Weighed Transformation Distribution Equation (Koppal)

Sl.No.	Week No.	Fitted Equation	R^2
1	15	y = -8.1872Ln(x) + 33.496	0.8058
2	16	y = -9.867Ln(x) + 41.543	0.9018
3	17	y = -12.533Ln(x) + 54.034	0.9264
4	18	y = -6.4511Ln(x) + 27.801	0.9144
5	19	y = -9.3141Ln(x) + 41.687	0.9199
6	20	y = -12.768Ln(x) + 59.419	0.9073
7	21	y = -25.235Ln(x) + 106.51	0.9175
8	22	y = -16.443Ln(x) + 75.668	0.9712
9	23	y = -33.168Ln(x) + 144.16	0.8302
10	24	y = -32.843Ln(x) + 145.19	0.939
11	25	y = -13.898Ln(x) + 61.872	0.9554
12	26	y = -22.886Ln(x) + 99.317	0.8987
13	27	y = -9.7991Ln(x) + 46.172	0.9634
14	28	y = -24.67Ln(x) + 106.85	0.8034
15	29	y = -13.099Ln(x) + 61.319	0.9539
16	30	y = -25.979Ln(x) + 117.11	0.9372
17	31	y = -22.98Ln(x) + 103.11	0.9393
18	32	y = -25.897Ln(x) + 114.6	0.9575
19	33	y = -13.193Ln(x) + 61.676	0.9778
20	34	y = -18.758Ln(x) + 83.605	0.9706
21	35	y = -47.232Ln(x) + 202.97	0.914
22	36	y = -35.698Ln(x) + 153.99	0.9266
23	37	y = -47.927Ln(x) + 210.29	0.9765
24	38	y = -47.927Ln(x) + 210.29	0.9765
25	39	y = -34.959Ln(x) + 169.06	0.9658
26	40	y = -42.106Ln(x) + 193.37	0.9565
27	41	y = -45.426Ln(x) + 190.54	0.8131
28	42	y = -28.499Ln(x) + 121.61	0.9307
29	43	y = -27.863Ln(x) + 117.99	0.9397
30	44	y = -17.686Ln(x) + 73.845	0.8471
31	45	y = -21.747Ln(x) + 89.875	0.8317
32	46	y = -37.638Ln(x) + 153.6	0.6375
33	47	y = -8.6738Ln(x) + 35.01	0.6478

Table 8: Consumptive Use (Evapotranspiration) Coefficient K, with respect to Class A Pan Evaporation

Percent of growth	Crop group							
	A	B	C	D	E	F	G	R
0	0.20	0.15	0.12	0.08	0.90	0.60	0.50	0.80
5	0.20	0.15	0.12	0.08	0.90	0.60	0.55	0.90
10	0.36	0.27	0.22	0.15	0.90	0.60	0.60	0.95
15	0.50	0.38	0.30	0.19	0.90	0.60	0.65	1.00
20	0.64	0.48	0.38	0.27	0.90	0.60	0.70	1.05
25	0.75	0.56	0.45	0.33	0.90	0.60	0.75	1.10
30	0.84	0.63	0.50	0.40	0.90	0.60	0.80	1.14
35	0.92	0.69	0.55	0.46	0.90	0.60	0.86	1.17
40	0.97	0.73	0.58	0.52	0.90	0.60	0.90	1.21
45	0.99	0.74	0.60	0.58	0.90	0.60	0.85	1.25
50	1.00	0.75	0.60	0.65	0.90	0.60	1.00	1.30
55	1.00	0.75	0.60	0.71	0.90	0.60	1.00	1.30
60	0.99	0.74	0.60	0.77	0.90	0.60	1.00	1.30
65	0.96	0.72	0.58	0.82	0.90	0.60	0.95	1.25
70	0.91	0.68	0.55	0.88	0.90	0.60	0.90	1.20
75	0.85	0.64	0.51	0.90	0.90	0.60	0.85	1.15
80	0.75	0.56	0.45	0.90	0.90	0.60	0.80	1.10
85	0.60	0.45	0.36	0.80	0.90	0.60	0.75	1.00
90	0.46	0.35	0.28	0.70	0.90	0.60	0.70	0.90
95	0.28	0.21	0.17	0.60	0.90	0.60	0.55	0.80
100	0.20	0.20	0.17	0.20	0.90	0.60	0.50	0.20

were estimated under rainfed. The variation of potential consumptive use under probability levels of 50%, 60%, 70%, 80%, and 90% were presented in figures 6 to 27. It is also presented deficit/surplus of rainfall at all probability levels have been presented in tables 10-13.

4.0 RESULTS AND DISCUSSION

4.1 Statistical Distribution of Rainfall

(a). Raichur District

Annual rainfall in Raichur district ranges from 430.00mm to 1020.00mm. Normal rainfall is estimated for 22 years 732.5 mm with standard deviation 163.11 mm, coefficient of variation +0.223 and coefficient of asymmetry +0.445. The overall situation of rainfall distribution over the years has been found to be reasonably dependable as probability of occurrence of 75% and 50% normal rainfall were estimated as 87 and 100 per cent respectively.

Rainfall distributed from April to December with maximum occurring during the months of July, August and September. Weekly rainfall values were used for the statistical distribution. Mean weekly rainfall ranges from 0 to 42.09mm. Most of the rainfall normally occurs between June to October. It can be observed that standard deviation ranges from 1.1 to 54.82, coefficient of variation from 0.8 to 3.14 and coefficient of asymmetry 1.67 to 6.28 in all the rainfall weeks. It implies that the distribution of rainfall is highly scattered and not dependable on weekly basis.

Table 9: Crop Calendar for Raichur and Koppal Districts

Sl. No.	Crop	Kharif		Rabi/Summer	
		Crop Period	Total Days	Crop Period	Total Days
1	Paddy	June-Oct	139	-	-
2	Jowar	June-Sept	107	Sept-Feb	145
3	Maize	June-Oct	123	Oct-Feb	123
4	Bajra	June-Sept	108	-	-
5	Wheat	-	-	Oct-Jan	108
6	Minor millet	June-Sept	108	-	-
7	Red gram	July-Jan	215	-	-
8	Bengal gram	-	-	Oct-Jan	107
9	Horse gram	Aug-Nov	122	-	-
10	Black gram	June-Aug	92	-	-
11	Green gram	June-Aug	76	Jan-Mar (S)	80
12	Copea	June-Sept	99	Jan-Mar (S)	80
13	Avare	June-Sept	99	Jan-Mar (S)	80
14	Groundnut	June-Sept	108	Dec-Mar (S)	105
15	Sesame	June-Sept	103	Jan-Apr (S)	105
16	Sunflower	June-Sept	99	Sept-Dec Jan-Apr (S)	106 96
17	Castor	June-Sept	108	-	-
18	Niger	June-Sept	93	-	-
19	Soyabean	June-Sept	99	Oct-Jan	99
20	Safflower	-	-	Sept-Jan	130
21	Linseed	-	-	Sept-Jan	130

Figure 6: Variation of Monthly Rainfall Probabilities and Consumptive Use of Crop

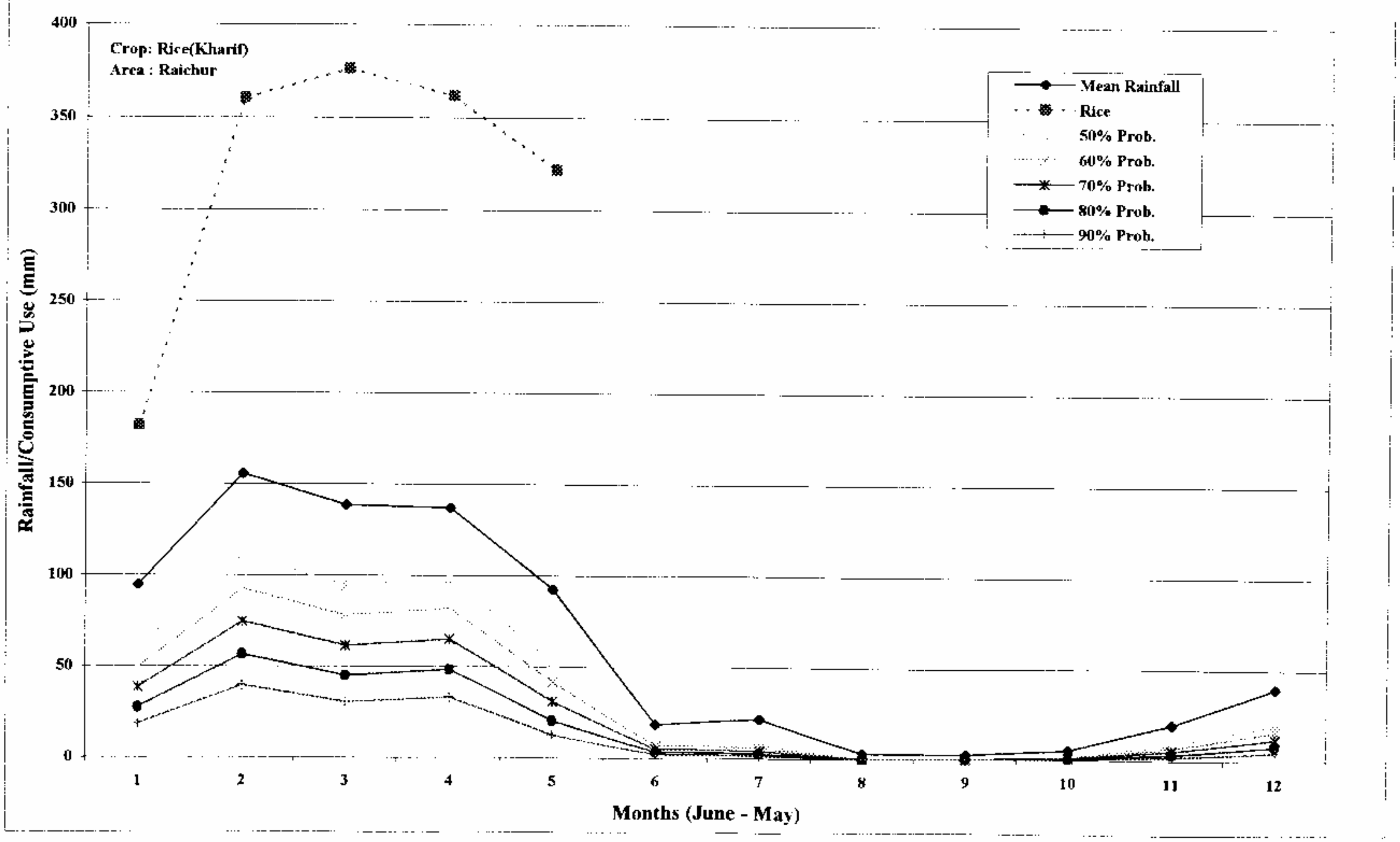

Figure 7: Variation of Monthly Rainfall Probabilities and Consumptive Use of Crop

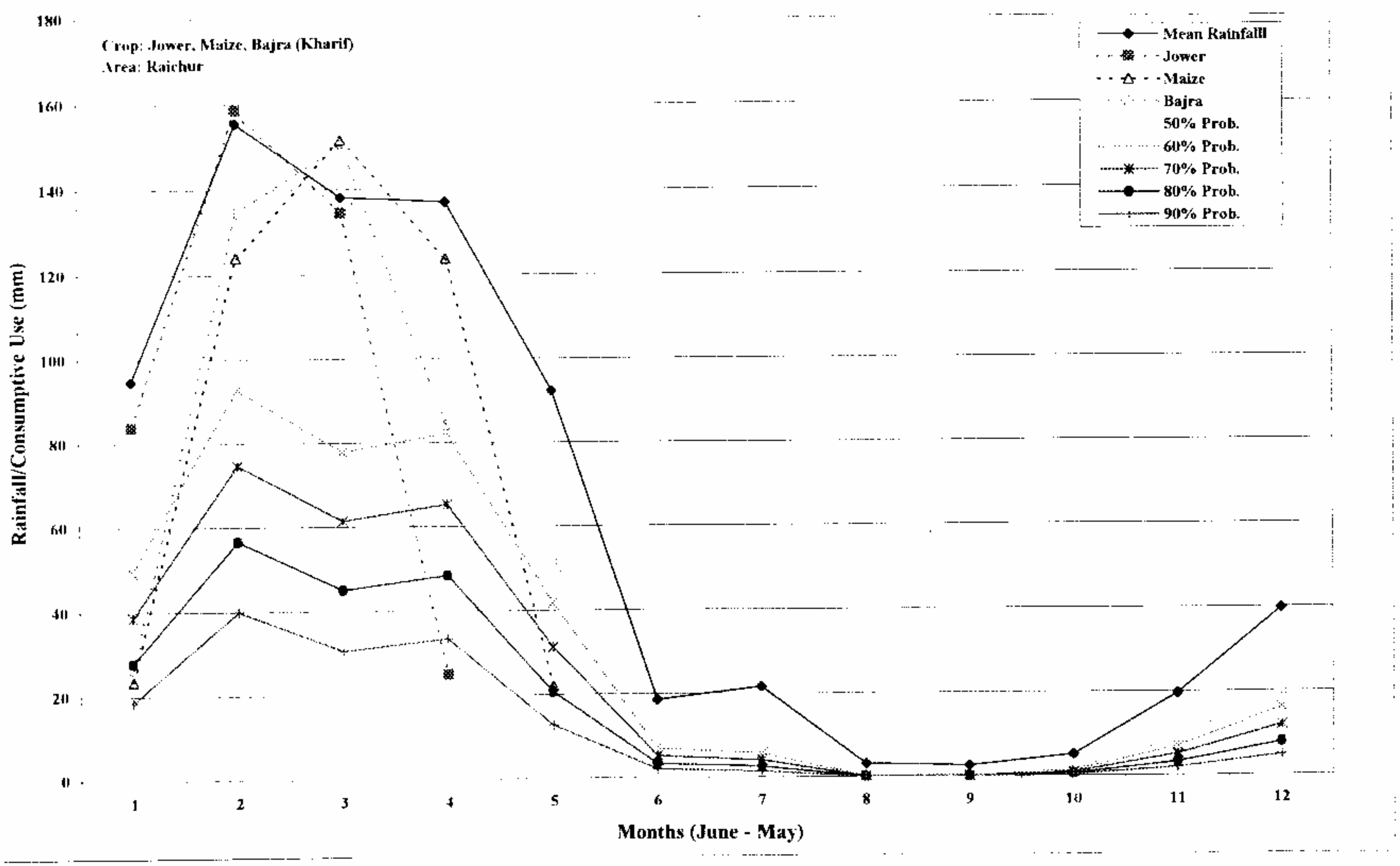

Figure 8: Variation of Monthly Rainfall Probabilities and Consumptive Use of Crop

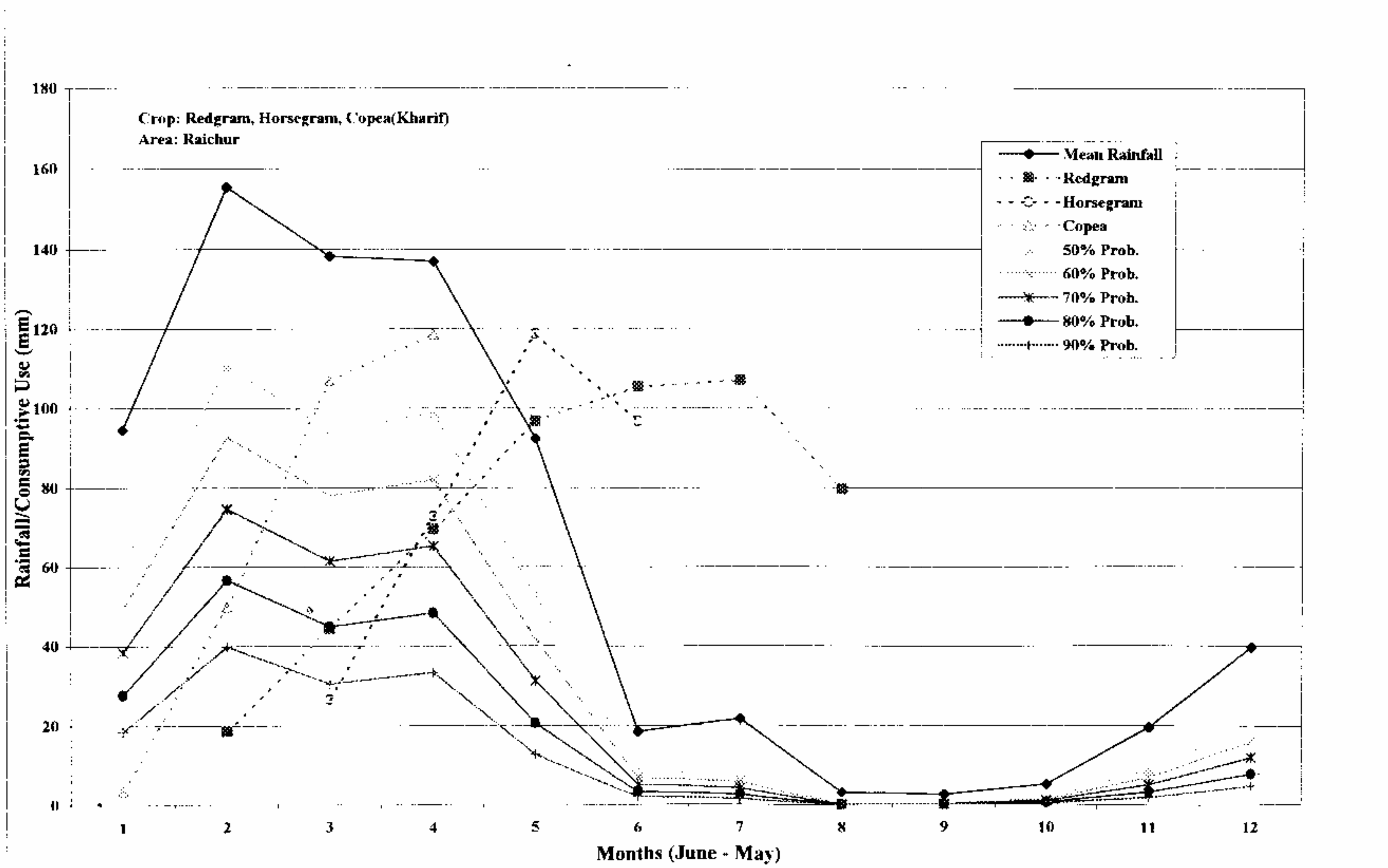

Figure 9: Variation of Monthly Rainfall Probabilities and Consumptive Use of Crop

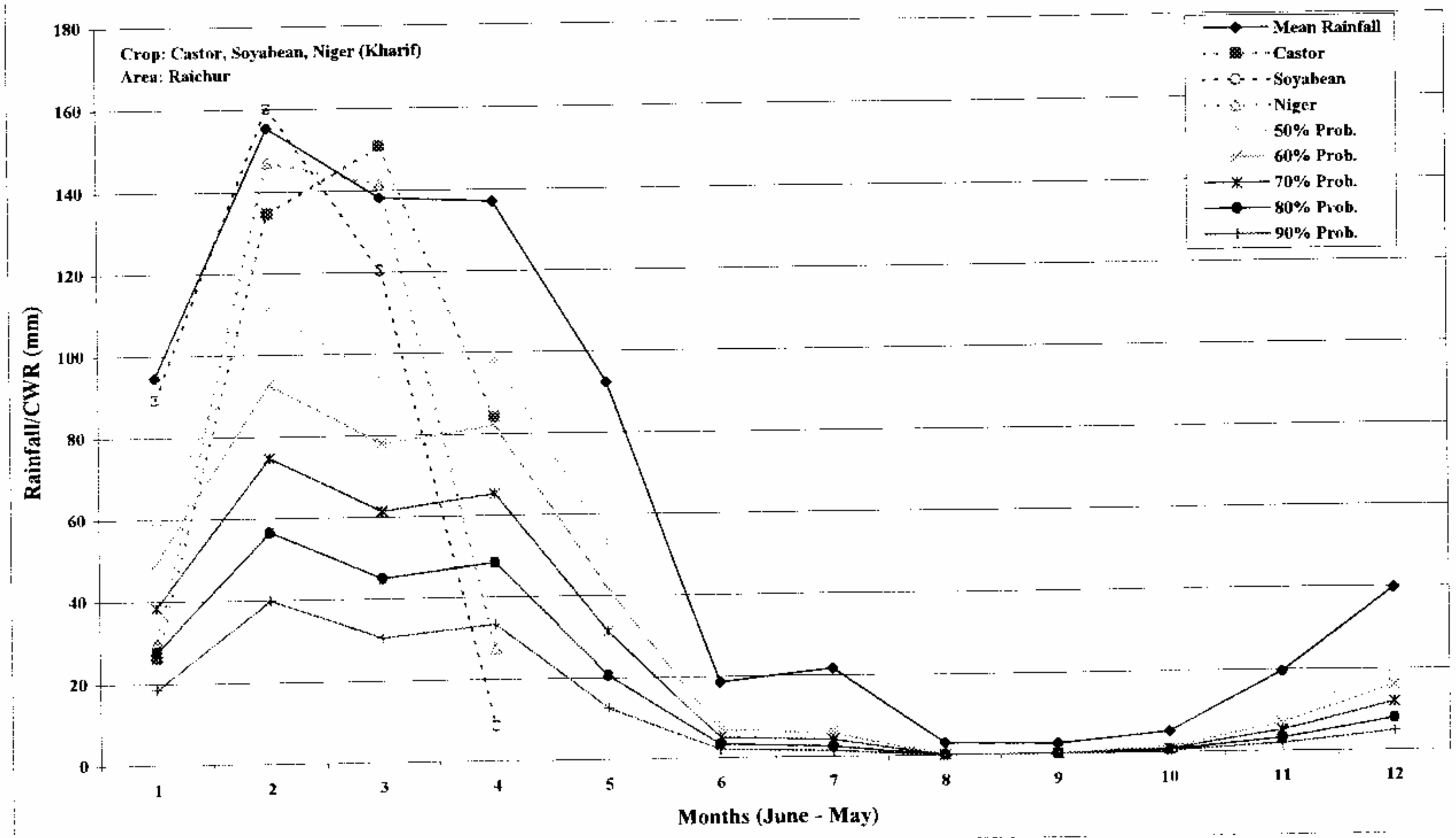

Figure 10: Variation of Monthly Rainfall Probabilities and Consumptive Use of Crop

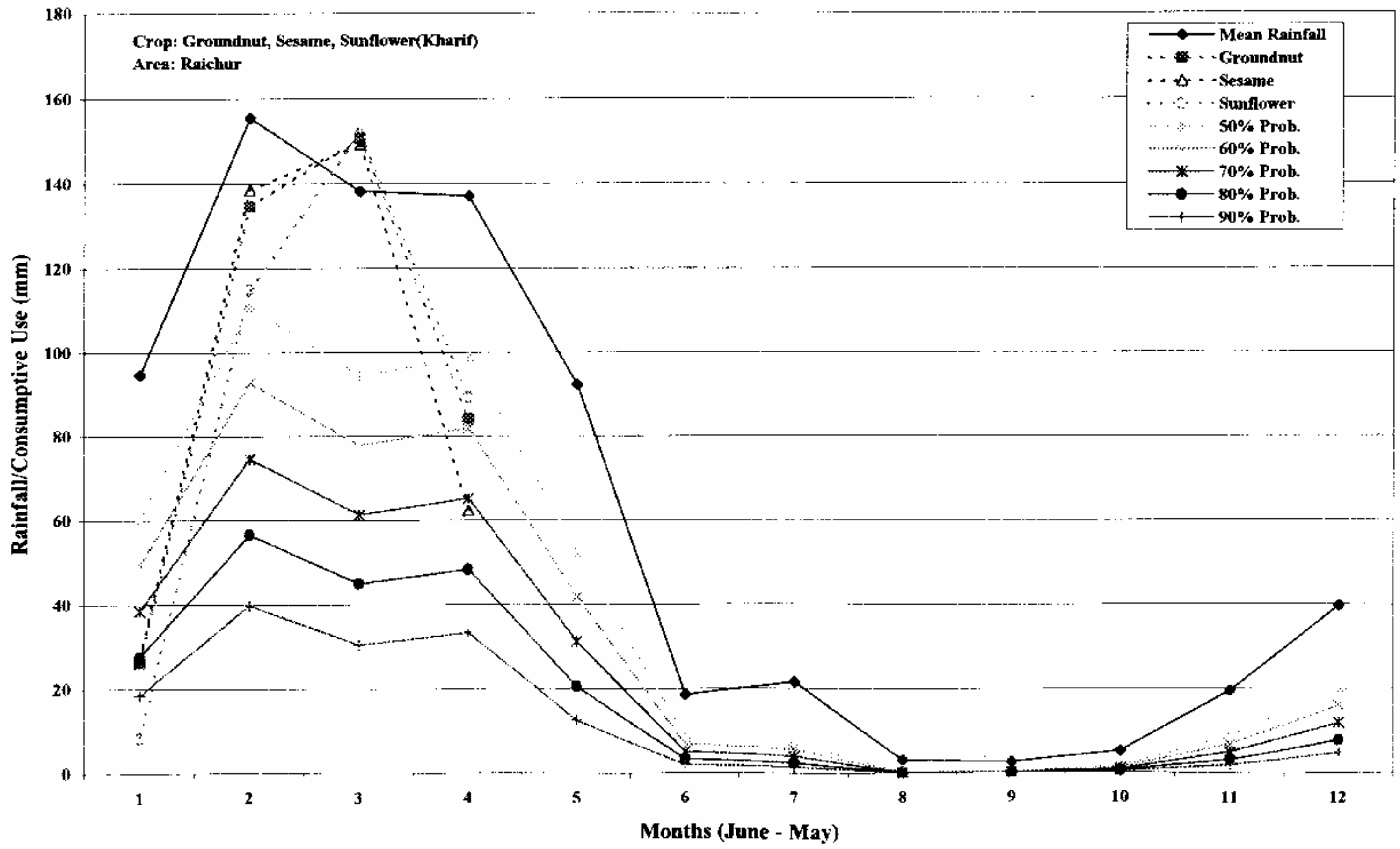

Figure 11: Variation of Monthly Rainfall Probabilities and Consumptive Use of Crop

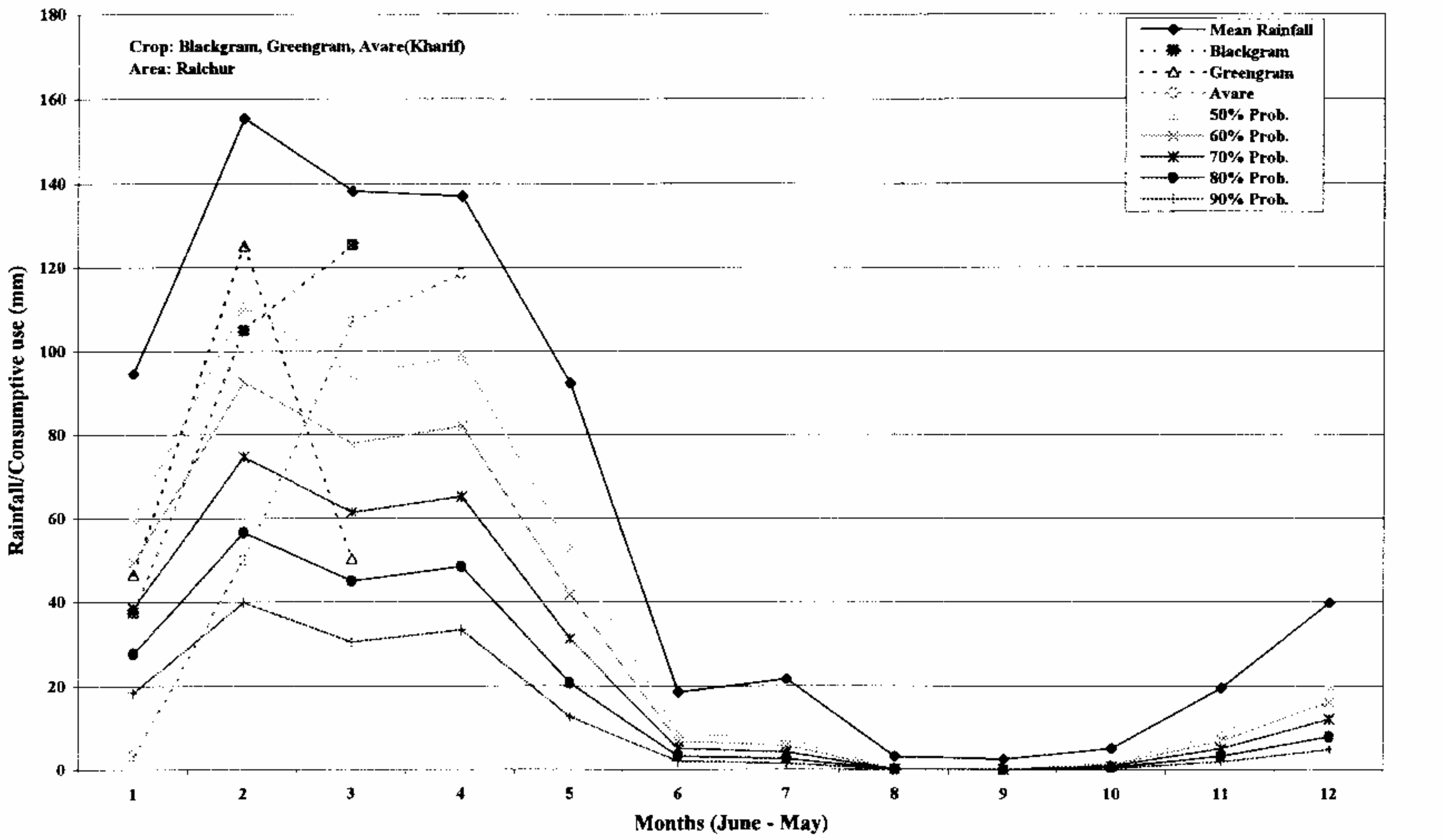

Figure 12: Variation of Monthly Rainfall Probabilities and Consumptive Use of Crop

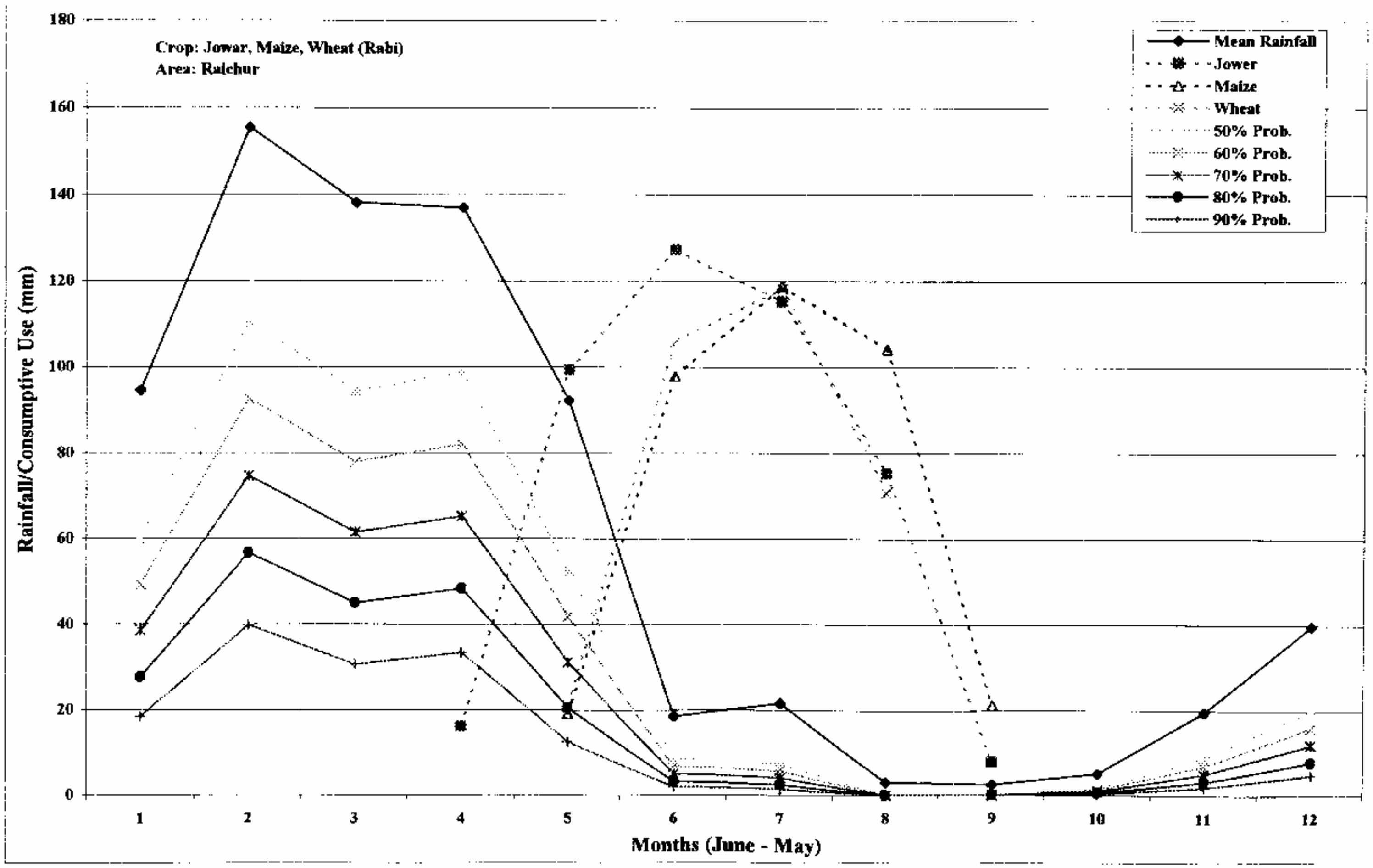

Figure 13: Variation of Monthly Rainfall Probabilities and Consumptive Use of Crop

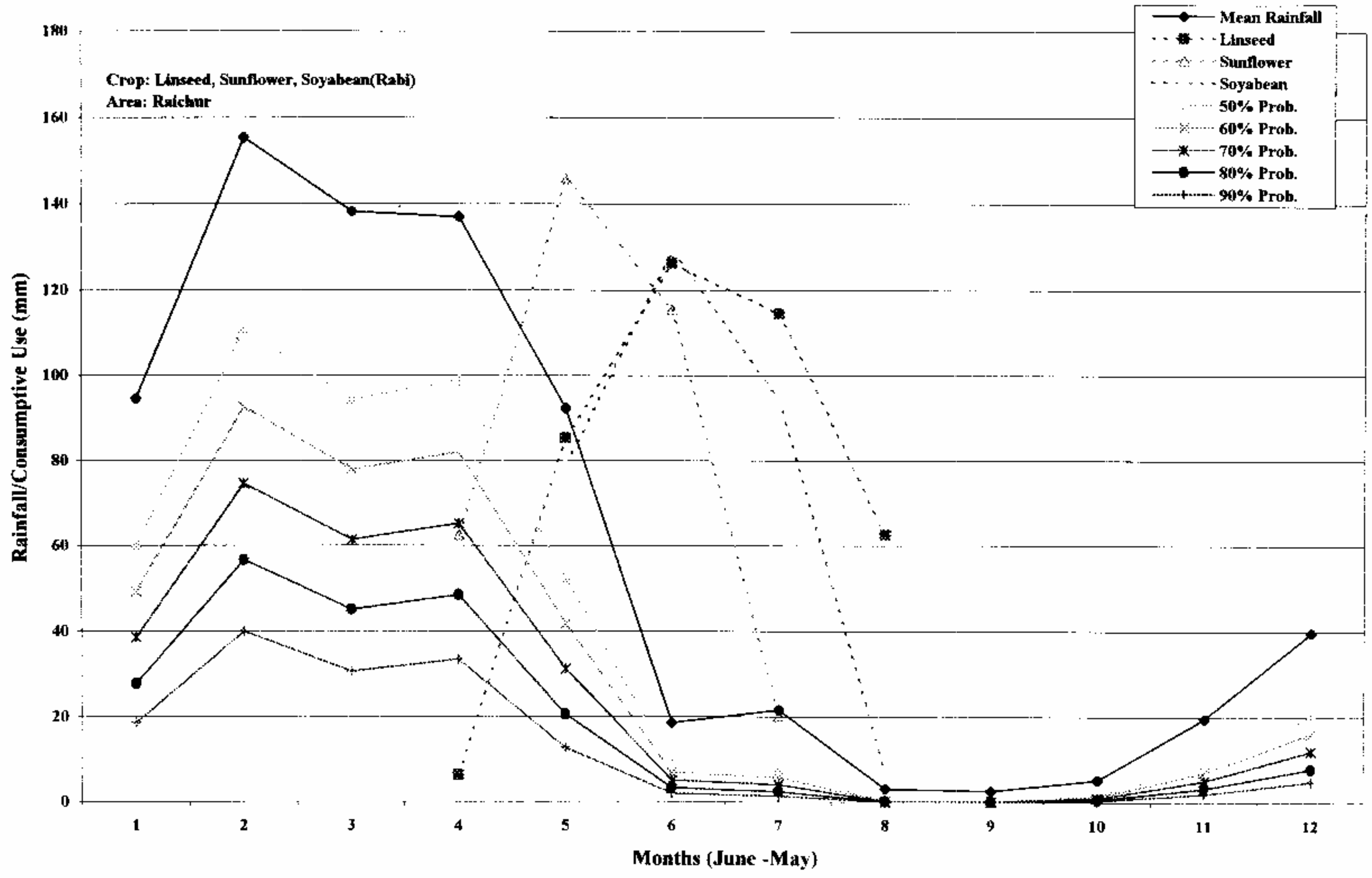

Figure 14: Variation of Monthly Rainfall Probabilities and Consumptive Use of Crop

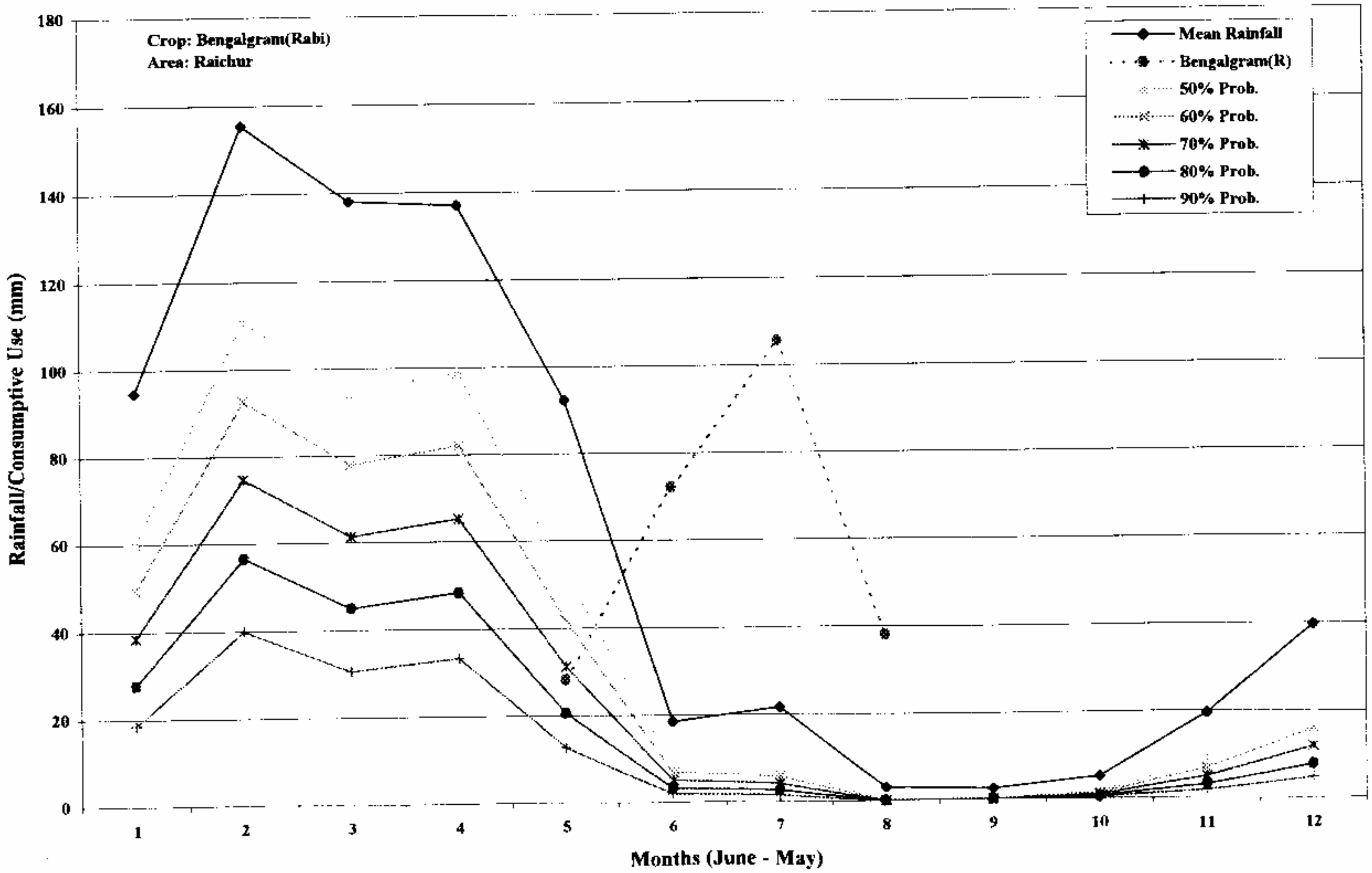

Figure 15: Variation of Monthly Rainfall Probabilities and Consumptive Use of Crop

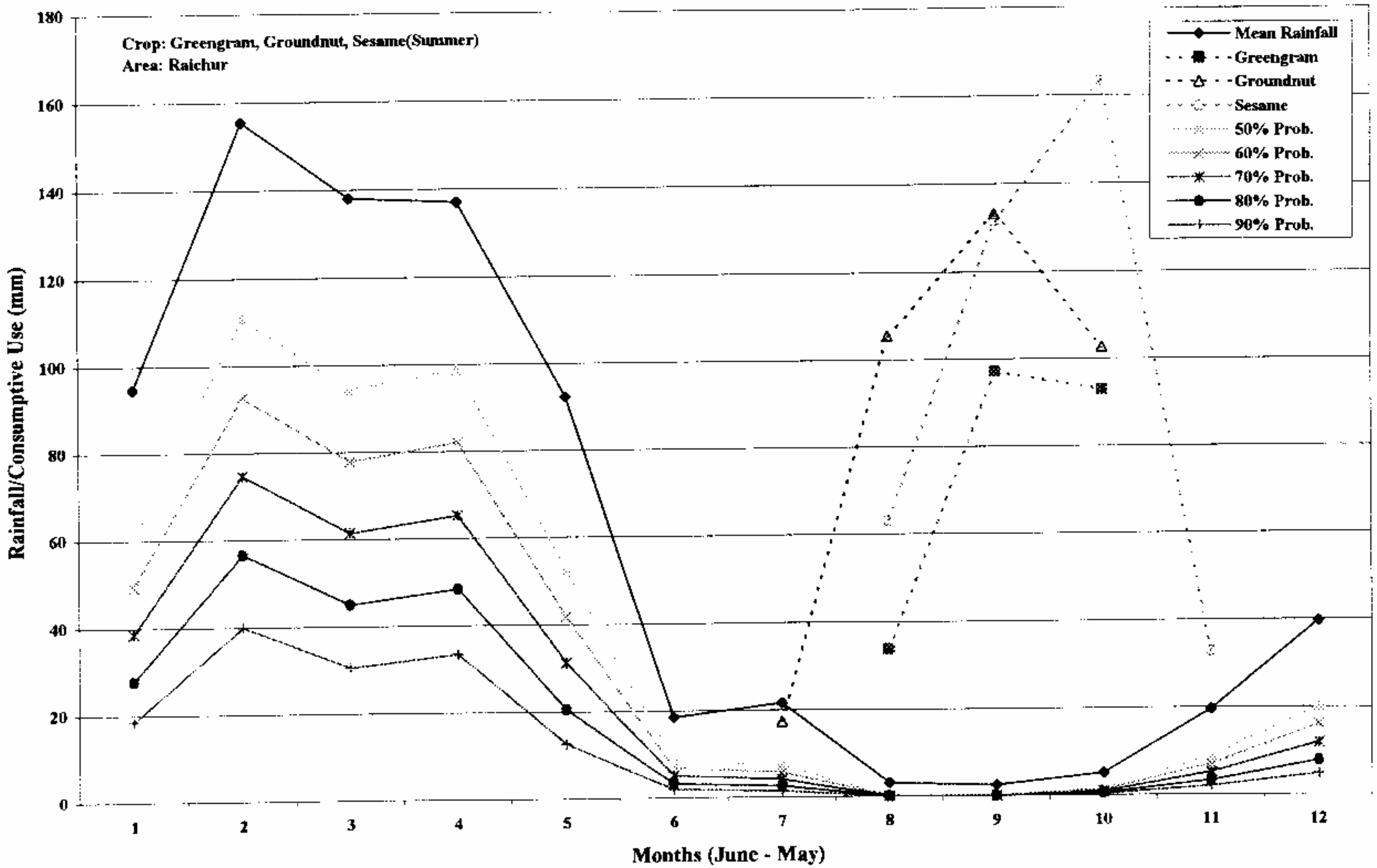

Figure 16: Variation of Monthly Rainfall Probabilities and Consumptive Use of Crop

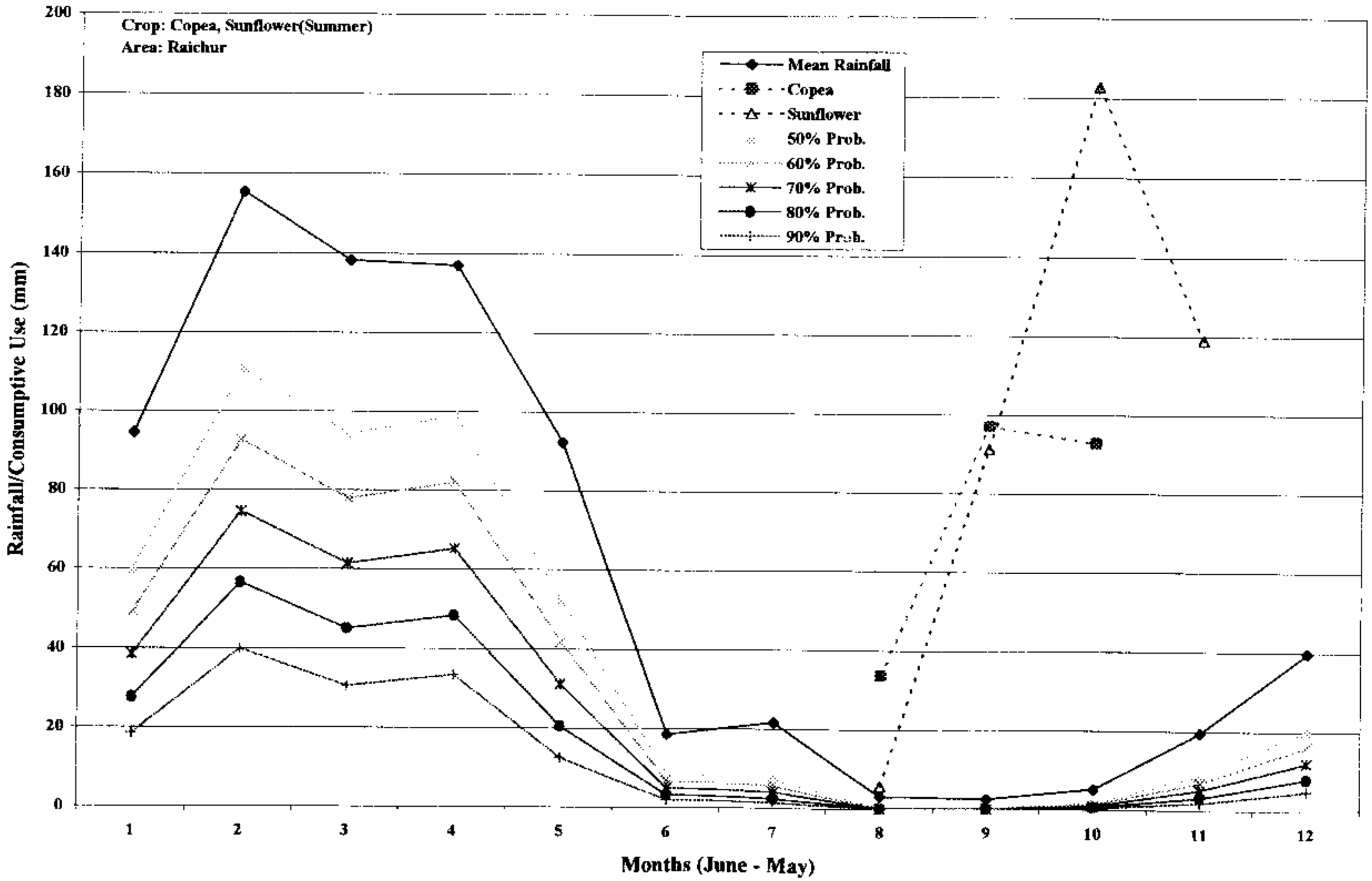

Figure 17: Variation of Monthly Rainfall Probabilities and Consumptive Use of Crop

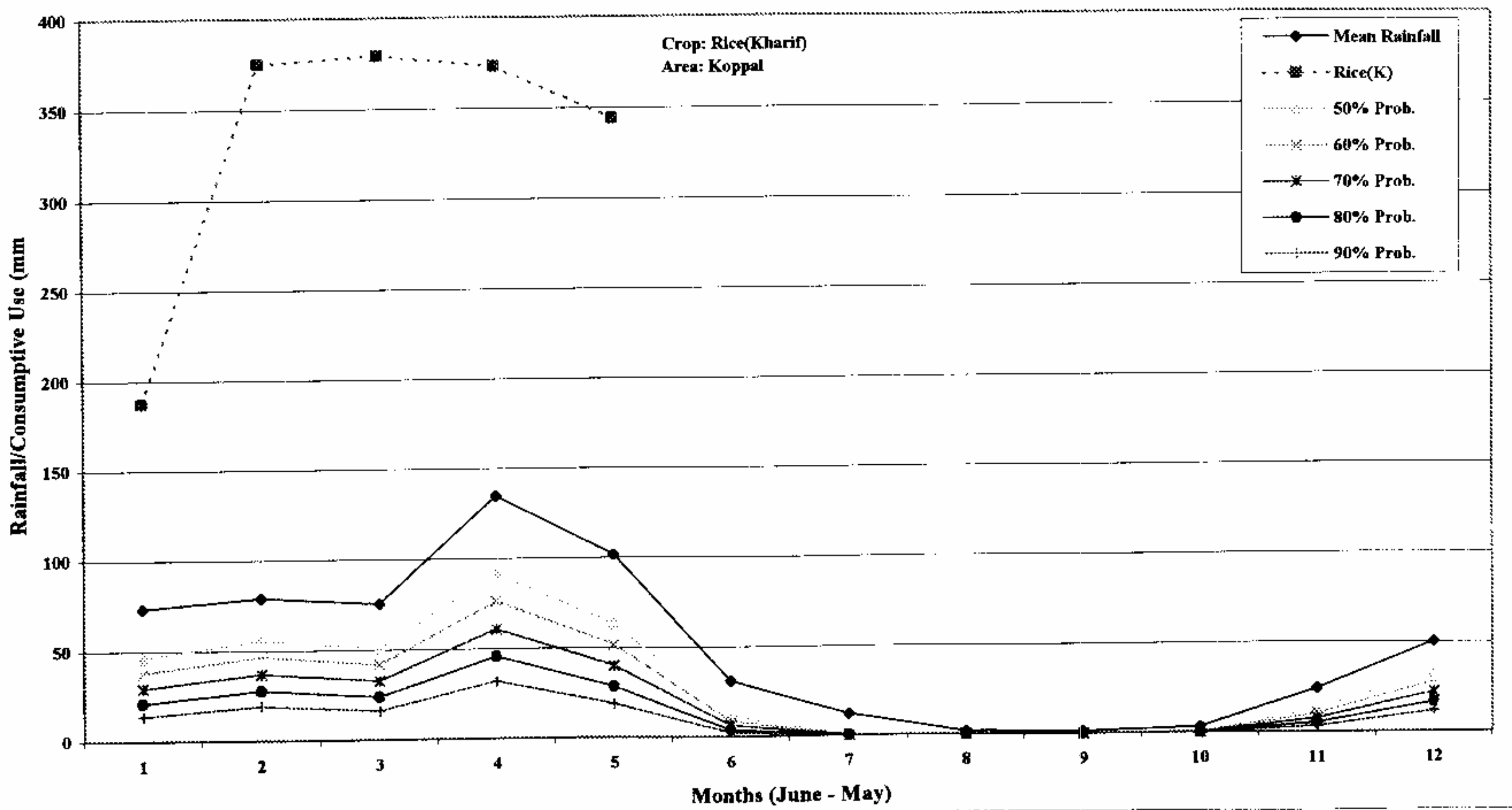

Figure 18: Variation of Monthly Rainfall Probabilities and Consumptive Use of Crop

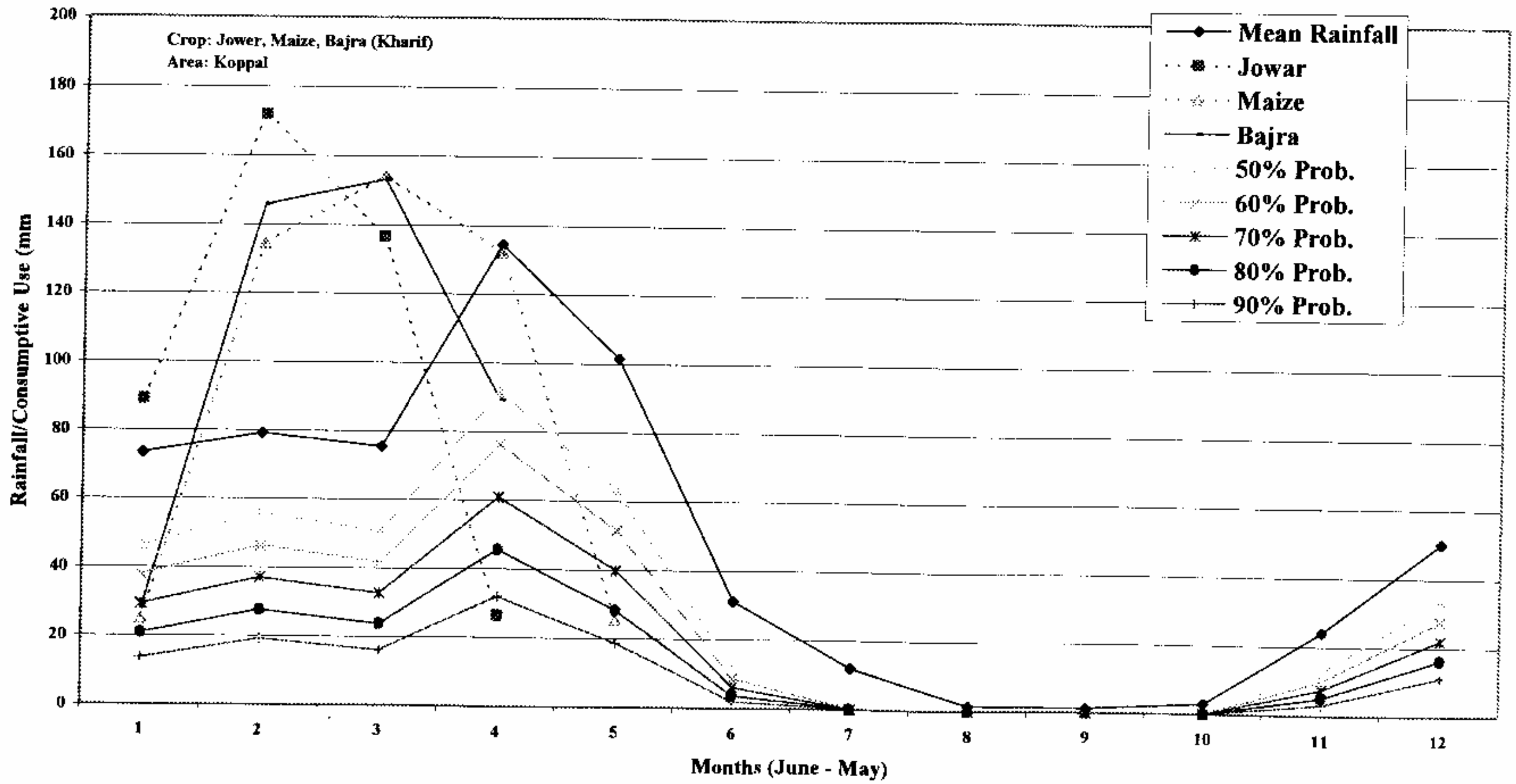

Figure 19: Variation of Monthly Rainfall Probabilities and Consumptive Use of Crop

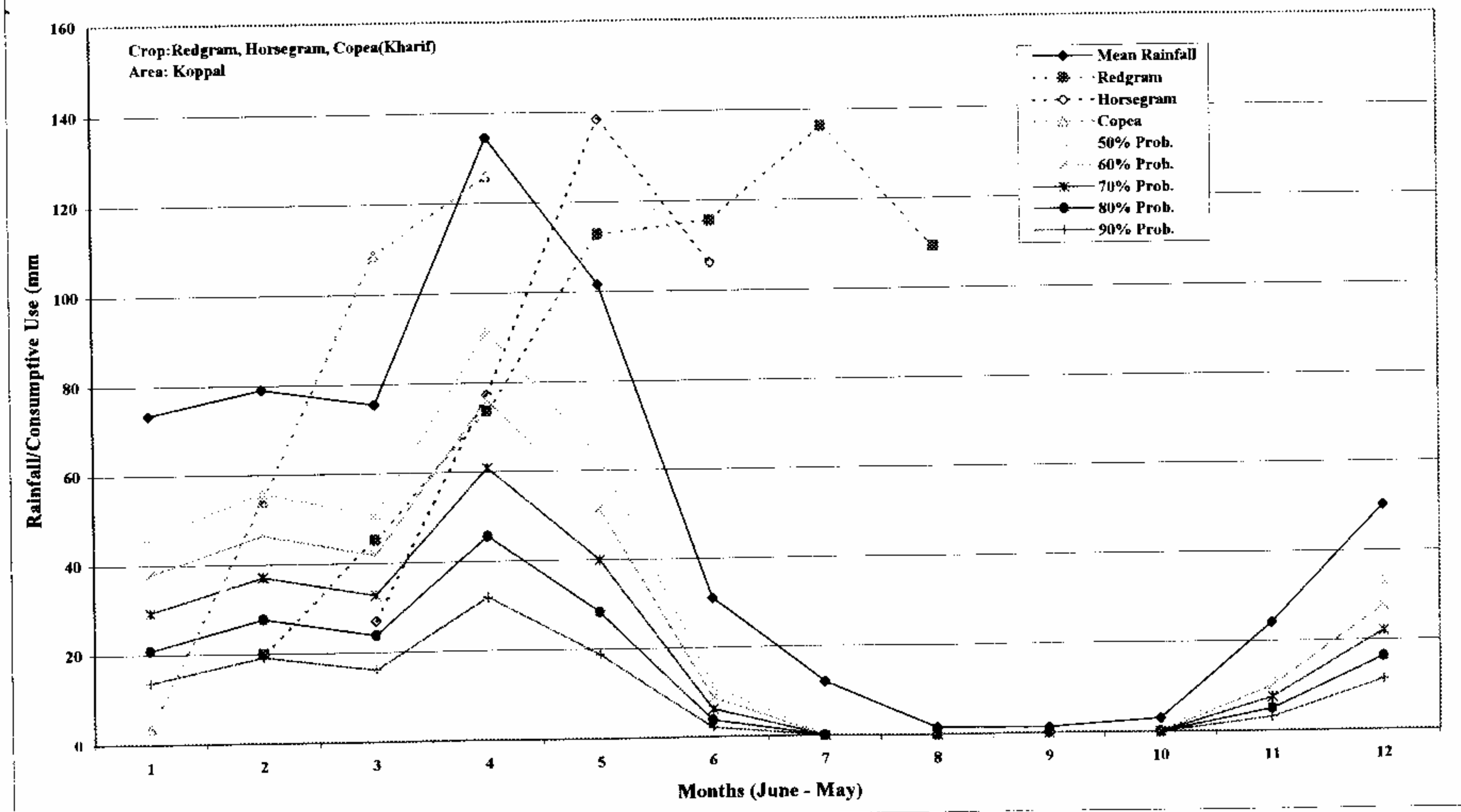

Figure 20: Variation of Monthly Rainfall Probabilities and Consumptive Use of Crop

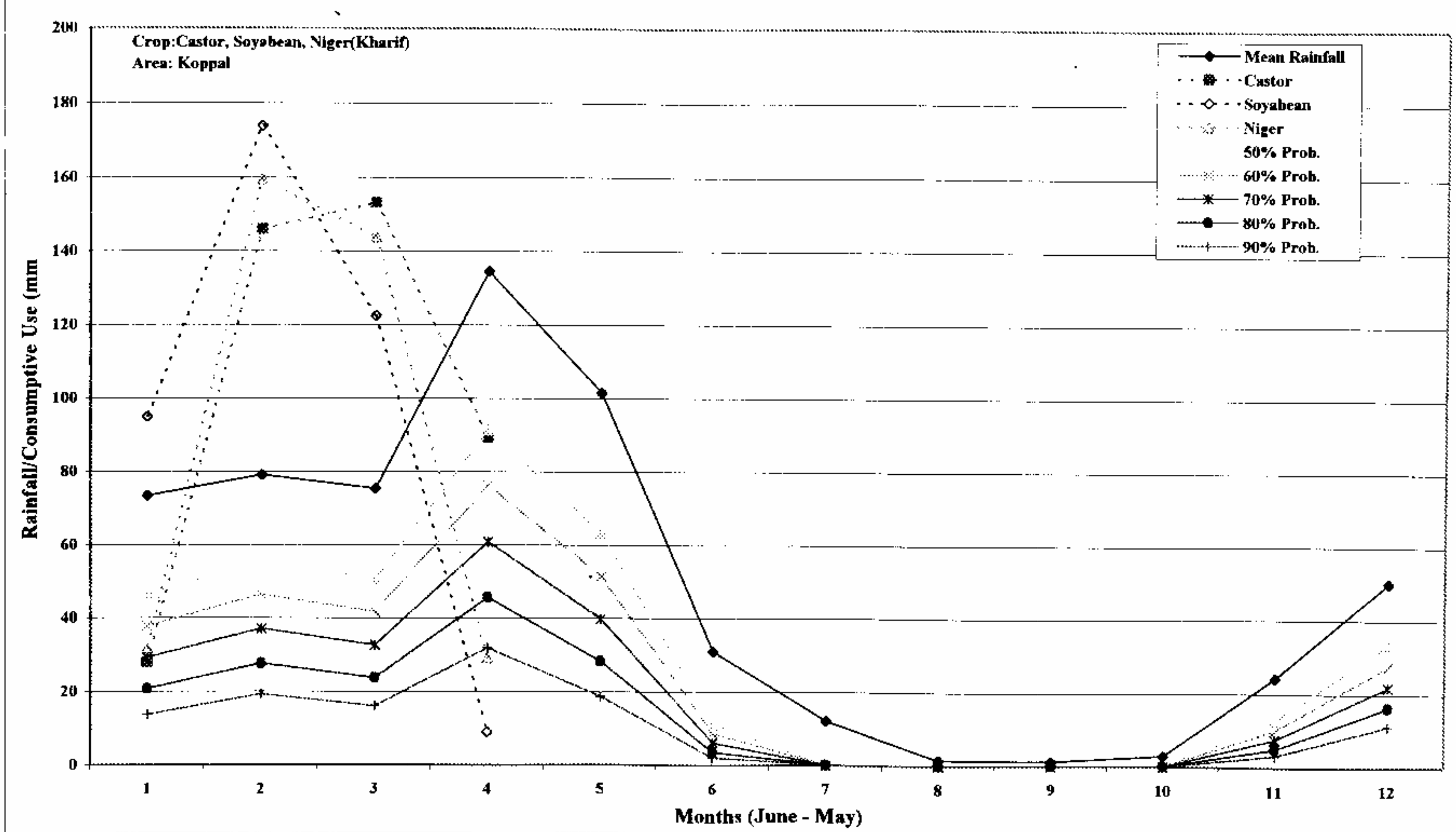

Figure 21: Variation of Monthly Rainfall Probabilities and Consumptive Use of Crop

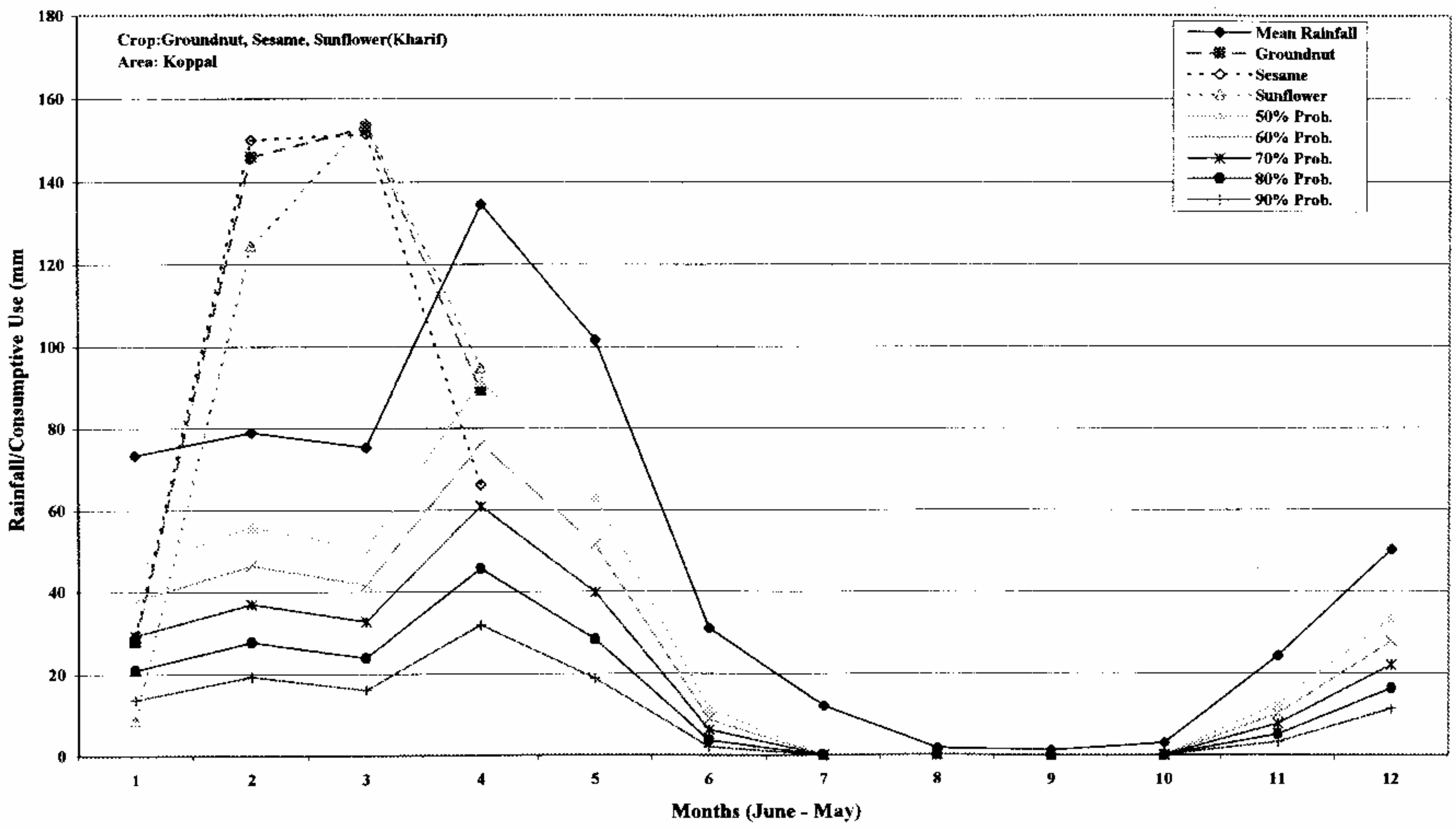

Figure 22: Variation of Monthly Rainfall Probabilities and Consumptive Use of Crop

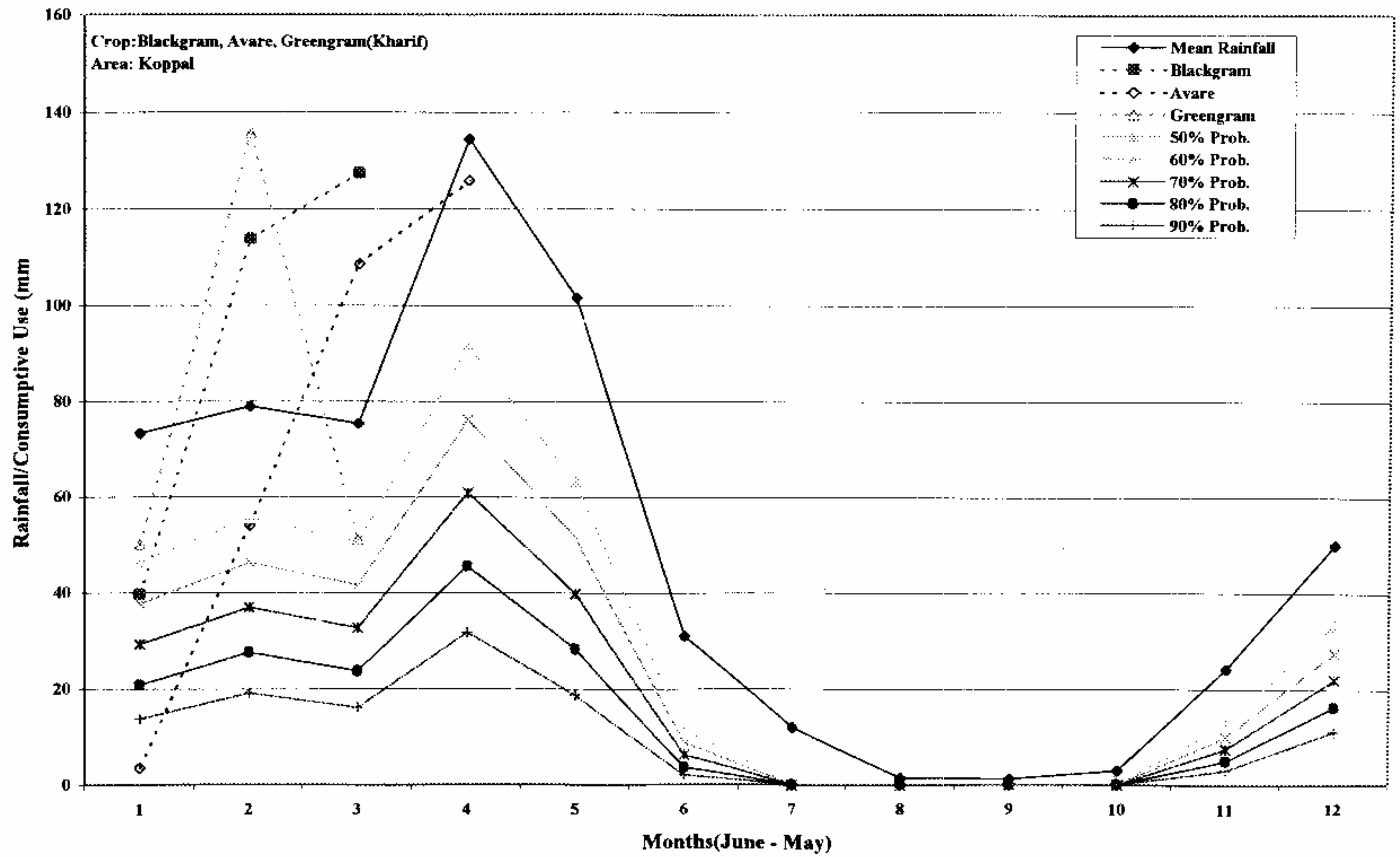

Figure: 23 Variation of Monthly Rainfall Probabilities and Consumptive Use of Crop

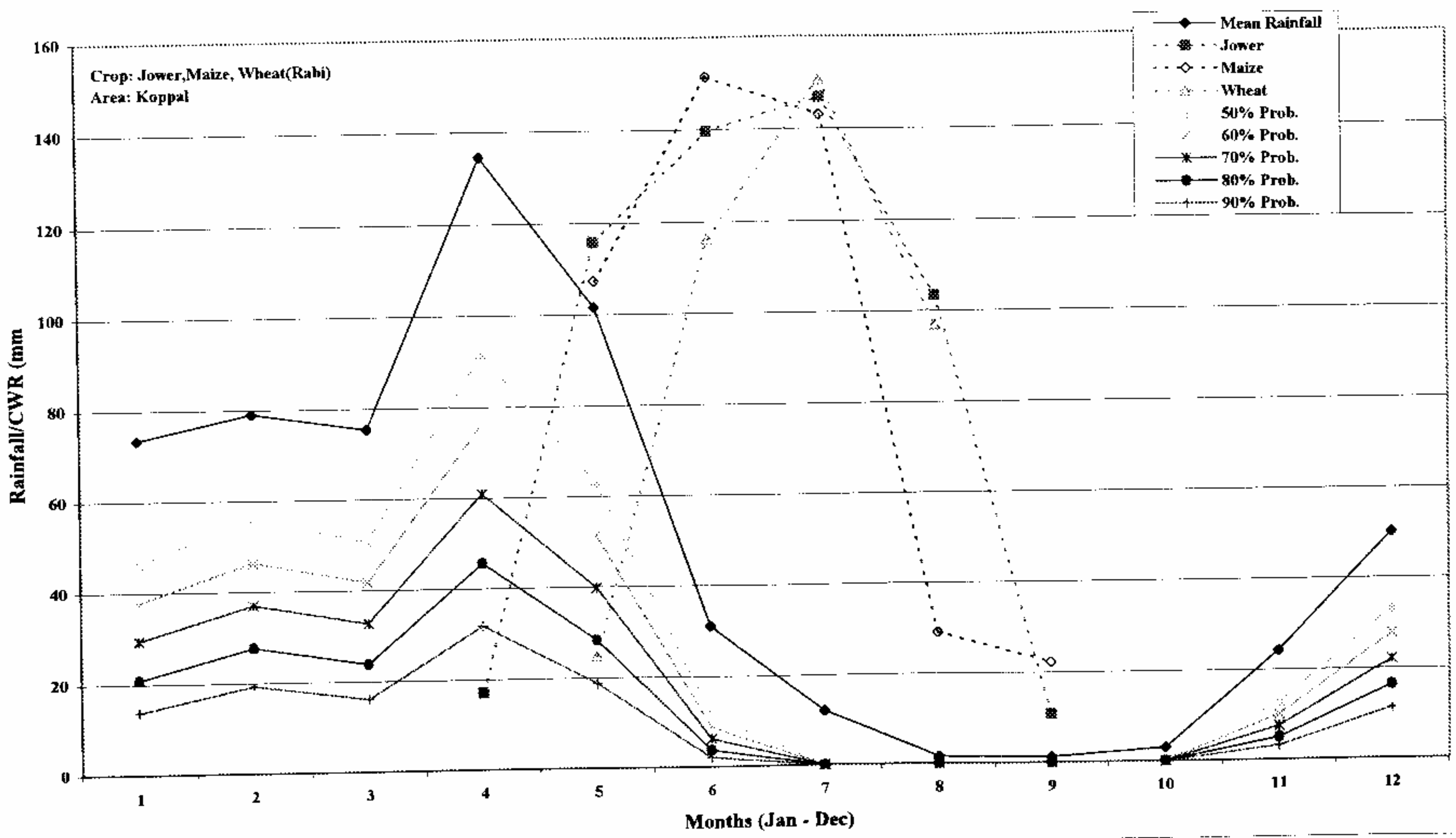

Figure 24: Variation of Monthly Rainfall Probabilities and Consumptive Use of Crop

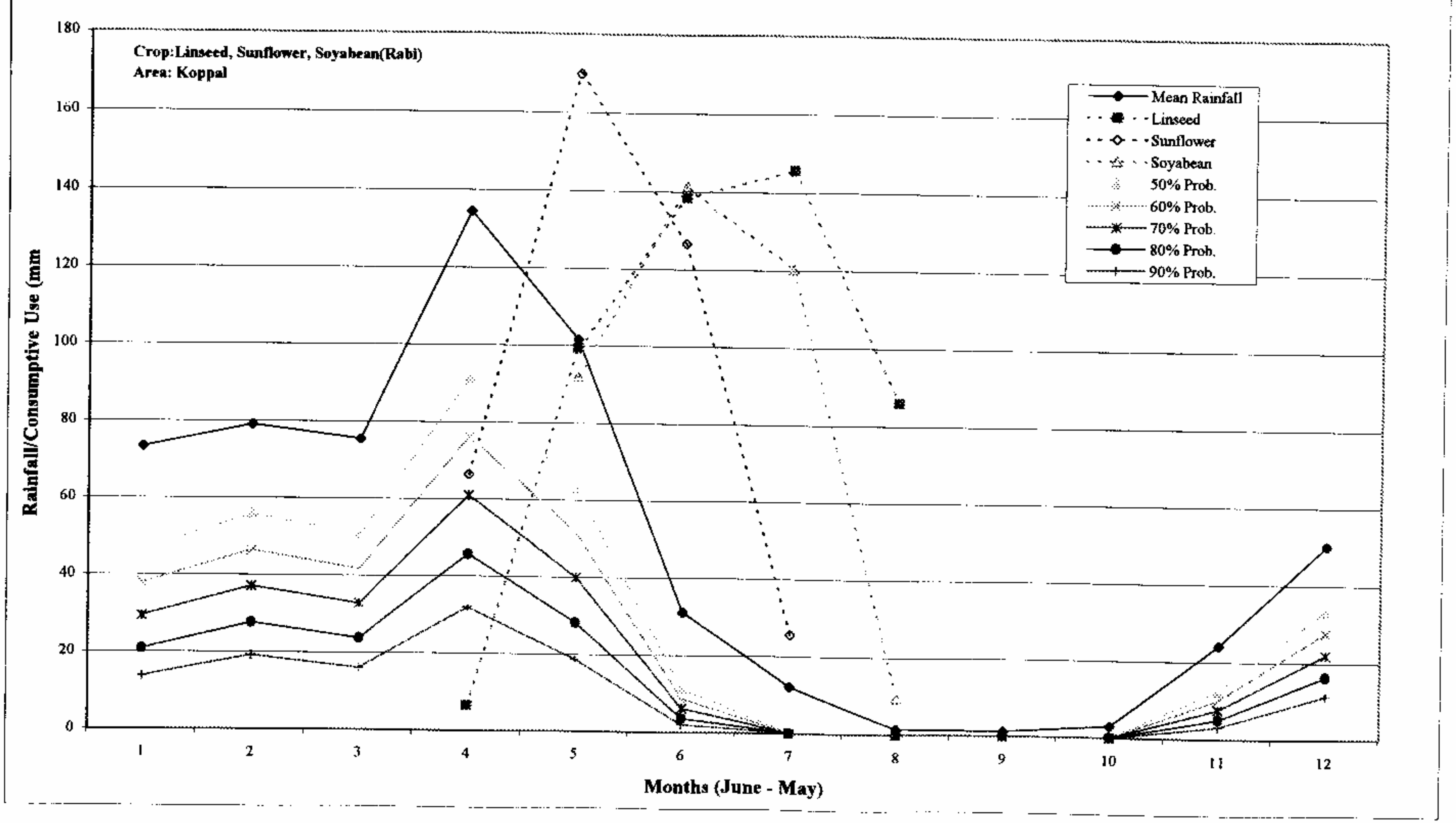

Figure 25: Variation of Monthly Rainfall Probabilities and Consumptive Use of Crop

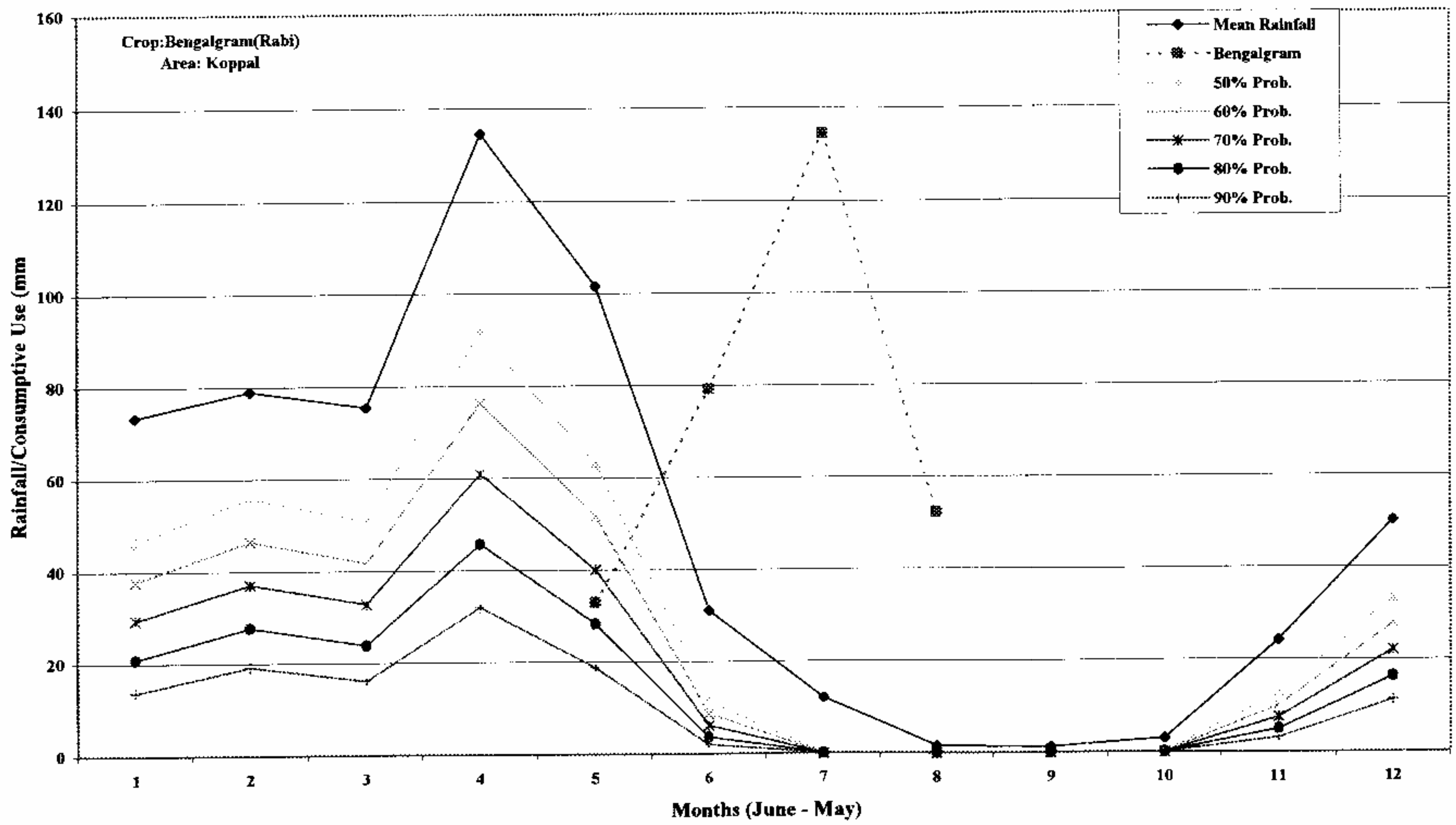

Figure 26: Variation of Monthly Rainfall Probabilities and Consumptive Use of Crop

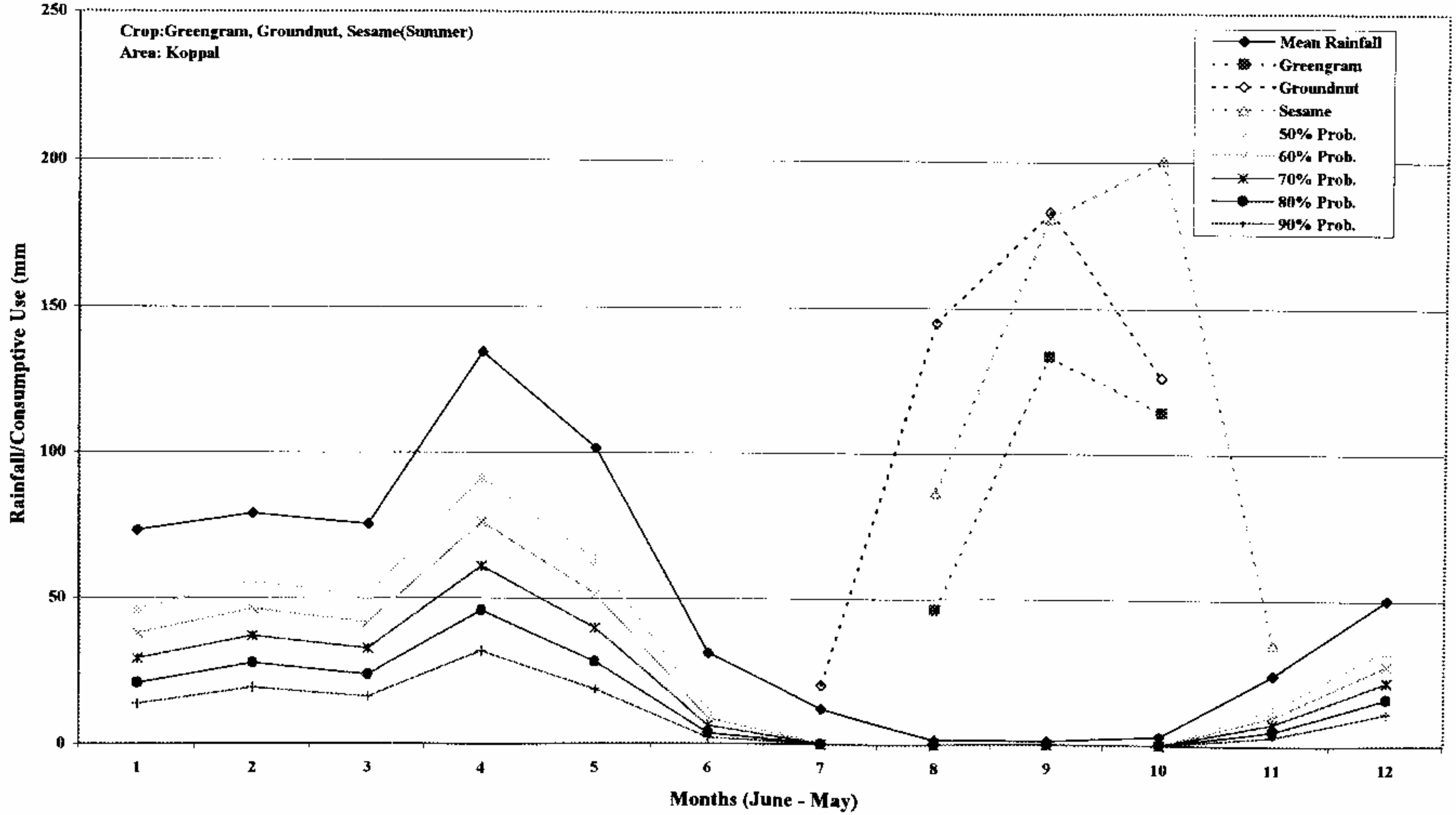

Figure 27: Variation of Monthly Rainfall Probabilities and Consumptive Use of Crop

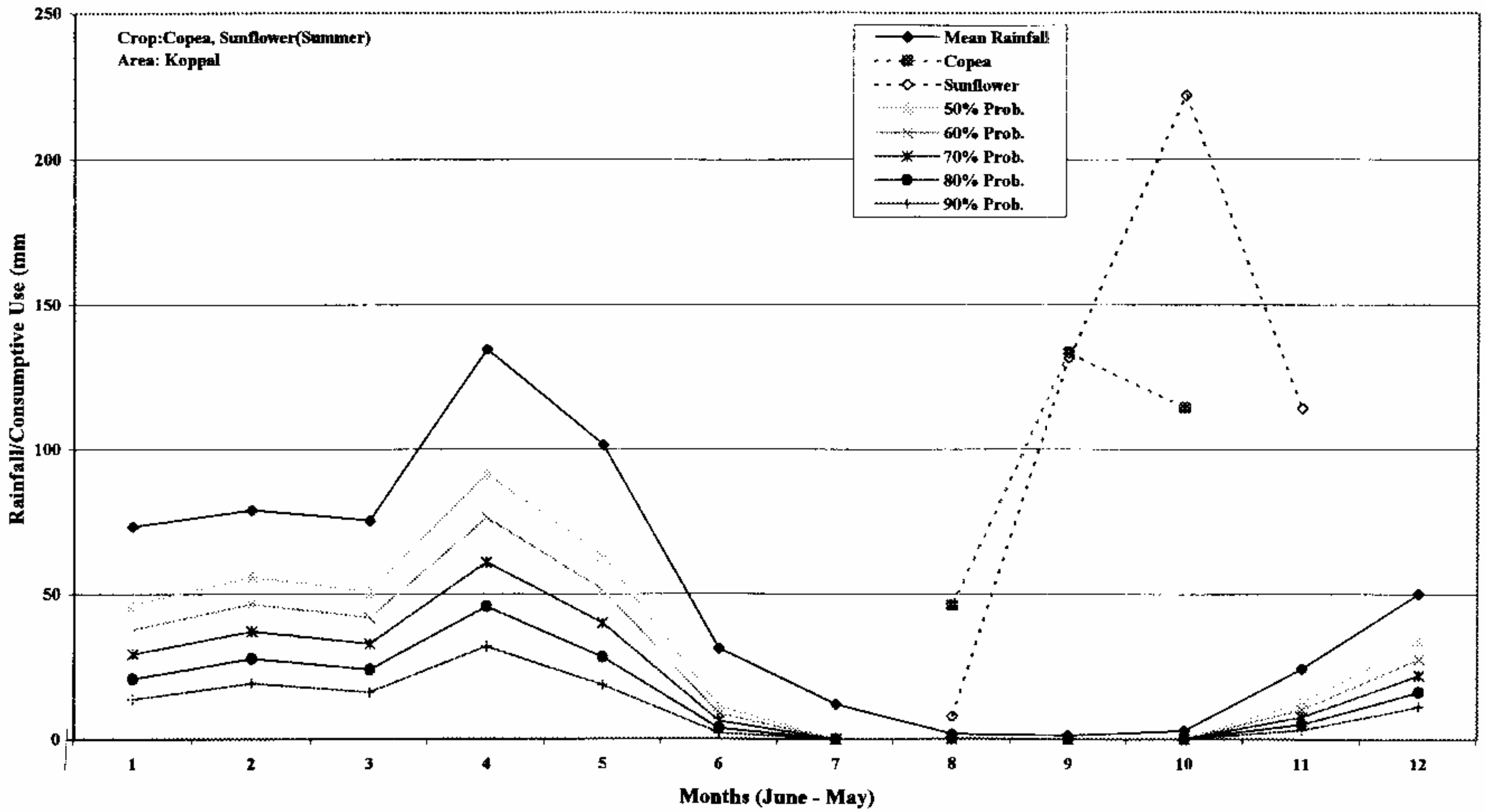

Table 10: Surplus and Deficit levels of Crop Water Under Different Probabilities in Raichur district (Kharif)

Crop	Surplus/Deficit (mm)						Month	Crop water
Kharif	Normal	50%	60%	70%	80%	90%		requirement
Rice	-87.15	-121.63	-132.45	-143.28	-154.1	-163.28	June	181.68
	-204.94	-249.67	-267.71	-285.76	-303.8	-320.55	July	360.34
	-237.94	-281.76	-298.22	-314.69	-331.15	-345.59	Aug	376.04
	-224.76	-262.9	-279.73	-296.54	-313.37	-328.4	Sept	361.7
	-229.48	-269.34	-279.97	-290.6	-301.23	-309.17	Oct	321.73
Jowar	10.88	-23.6	-34.42	-45.25	-56.07	-65.25	June	83.65
	-3.08	-47.81	-65.85	-83.9	-101.94	-118.69	July	158.48
	3.71	-40.11	-56.57	-73.04	-89.5	-103.94	Aug	134.39
	112.19	74.05	57.22	40.41	23.58	8.55	Sept	24.75
Maize	71.12	36.64	25.82	14.99	4.17	-5.01	June	23.41
	31.4	-13.33	-31.37	-49.42	-67.46	-84.21	July	124
	-13.51	-57.33	-73.79	-90.26	-106.72	-121.16	Aug	151.61
	13.34	-24.8	-41.63	-58.44	-75.27	-90.3	Sept	123.6
	70.37	30.51	19.88	9.25	-1.38	-9.32	Oct	21.88
Sesame	67.28	32.8	21.98	11.15	0.33	-8.85	June	27.25
	17.09	-27.64	-45.68	-63.73	-81.77	-98.52	July	138.31
	-10.95	-54.77	-71.23	-87.7	-104.16	-118.6	Aug	149.05
	74.67	36.53	19.7	2.89	-13.94	-28.97	Sept	62.27
Niger	64.77	30.29	19.47	8.64	-2.18	-11.36	June	27.25
	8.44	-36.29	-54.33	-72.38	-90.42	-107.17	July	138.31
	-3.27	-47.09	-63.55	-80.02	-96.48	-110.92	Aug	149.05
	109.57	71.43	54.6	37.79	20.96	5.93	Sept	62.27
Soyabean	5.3	-29.18	-40	-50.83	-61.65	-70.83	June	89.23
	139.41	94.68	76.64	58.59	40.55	23.8	July	15.99
	126.06	82.24	65.78	49.31	32.85	18.41	Aug	12.04
	128.41	90.27	73.44	56.63	39.8	24.77	Sept	8.53
Bajra/	68.38	33.9	23.08	12.25	1.43	-7.75	June	89.23
M.millet/	20.95	-23.78	-41.82	-59.87	-77.91	-94.66	July	15.99
G.nut	-12.51	-56.33	-72.79	-89.26	-105.72	-120.16	Aug	12.04
	52.96	14.82	-2.01	-18.82	-35.65	-50.68	Sept	8.53
Sunflower	86.28	51.8	40.98	30.15	19.33	10.15	June	8.25
	40.63	-4.1	-22.14	-40.19	-58.23	-74.98	July	114.77
	-13.51	-57.33	-73.79	-90.26	-106.72	-121.16	Aug	151.61
	47.71	9.57	-7.26	-24.07	-40.9	-55.93	Sept	89.23
Blackgram	57.23	22.75	11.93	1.1	-9.72	-18.9	June	37.3
	50.5	5.77	-12.27	-30.32	-48.36	-65.11	July	104.9
	12.87	-30.95	-47.41	-63.88	-80.34	-94.78	Aug	125.23
Greengram	48.12	13.64	2.82	-8.01	-18.83	-28.01	June	46.41
	30.29	-14.44	-32.48	-50.53	-68.57	-85.32	July	125.11
	87.9	44.08	27.62	11.15	-5.31	-19.75	Aug	50.2
Horsegram	111.6	67.78	51.32	34.85	18.39	3.95	Aug	26.5
	64.26	26.12	9.29	-7.52	-24.35	-39.38	Sept	72.68
	-26.48	-66.34	-76.97	-87.6	-98.23	-106.17	Oct	118.73
	-78.29	-88.18	-89.98	-91.77	-93.57	-94.85	Nov	96.77
Redgram	136.98	92.25	74.21	56.16	38.12	21.37	July	18.42
	93.78	49.96	33.5	17.03	0.57	-13.87	Aug	44.32
	67.59	29.45	12.62	-4.19	-21.02	-36.05	Sept	69.35
	-4.5	-44.36	-54.99	-65.62	-76.25	-84.19	Oct	96.75
	-86.85	-96.74	-98.54	-100.33	-102.13	-103.41	Nov	105.33
	-85.54	-99.75	-101.39	-103.01	-104.65	-105.71	Dec	107.06
	-76.49	-79.52	-79.52	-79.52	-79.52	-79.52	Jan	79.52
Copea/	91.25	56.77	45.95	35.12	24.3	15.12	June	3.28
Avare	105.57	60.84	42.8	24.75	6.71	-10.04	July	49.83
	31.28	-12.54	-29	-45.47	-61.93	-76.37	Aug	106.82
	18.41	-19.73	-36.56	-53.37	-70.2	-85.23	Sept	118.53

Table 11: Surplus and Deficit levels of Crop Water Under Different Probabilities in Raichur district (Rabi/Summer)

Crop	Surplus/Deficit (mm)						Month	Crop water
Rabi/Summer	Normal	50%	60%	70%	80%	90%		requirement
Jowar	120.98	82.84	66.01	49.2	32.37	17.34	Sept	15.96
	-7.11	-46.97	-57.6	-68.23	-78.86	-86.8	Oct	99.36
	-108.82	-118.71	-120.51	-122.3	-124.1	-125.38	Nov	127.3
	10	-4.21	-5.85	-7.47	-9.11	-10.17	Dec	11.52
	-72.23	-75.26	-75.26	-75.26	-75.26	-75.26	Jan	75.26
	-5.32	-7.81	-7.81	-7.81	-7.81	-7.81	Feb	7.81
Maize	73.25	33.39	22.76	12.13	1.5	-6.44	Oct	19
	-79.3	-89.19	-90.99	-92.78	-94.58	-95.86	Nov	97.78
	-97.34	-111.55	-113.19	-114.81	-116.45	-117.51	Dec	118.86
	-101.14	-104.17	-104.17	-104.17	-104.17	-104.17	Jan	104.17
	-18.62	-21.11	-21.11	-21.11	-21.11	-21.11	Feb	21.11
Soyabean	13.34	-26.52	-37.15	-47.78	-58.41	-9.32	Oct	78.91
	-110.35	-120.24	-122.04	-123.83	-125.63	1.92	Nov	128.83
	-72.91	-87.12	-88.76	-90.38	-92.02	1.35	Dec	94.43
	-3.94	-6.97	-6.97	-6.97	-6.97	-6.97	Jan	6.97
Wheat	71.05	31.19	20.56	9.93	-0.7	-8.64	Oct	21.2
	-87.48	-97.37	-99.17	-100.96	-102.76	-104.04	Nov	105.96
	-96.76	-110.97	-112.61	-114.23	-115.87	-116.93	Dec	118.28
	-67.69	-70.72	-70.72	-70.72	-70.72	-70.72	Jan	70.72
Sunflower	74.47	36.33	19.5	2.69	-14.14	-29.17	Sept	62.47
	-53.51	-93.37	-104	-114.63	-125.26	-133.2	Oct	145.76
	-96.95	-106.84	-108.64	-110.43	-112.23	-113.51	Nov	115.43
	1.45	-12.76	-14.4	-16.02	-17.66	-18.72	Dec	20.07
Safflower	130.81	92.67	75.84	59.03	42.2	27.17	Sept	6.13
	6.98	-32.88	-43.51	-54.14	-64.77	-72.71	Oct	85.27
	-107.78	-117.67	-119.47	-121.26	-123.06	-124.34	Nov	126.26
	-92.85	-107.06	-108.7	-110.32	-111.96	-113.02	Dec	114.37
	-59.54	-62.57	-62.57	-62.57	-62.57	-62.57	Jan	62.57
Linseed	130.81	92.67	75.84	59.03	42.2	27.17	Sept	6.13
	6.98	-32.88	-43.51	-54.14	-64.77	-72.71	Oct	85.27
	-107.78	-117.67	-119.47	-121.26	-123.06	-124.34	Nov	126.26
	-92.85	-107.06	-108.7	-110.32	-111.96	-113.02	Dec	114.37
	-59.54	-62.57	-62.57	2.59	-14.24	-29.27	Jan	62.57
Bengalgram	64.15	24.29	13.66	3.03	-7.6	-15.54	Oct	28.1
	-53.64	-63.53	-65.33	-67.12	-68.92	-70.2	Nov	72.12
	-84.01	-98.22	-99.86	-101.48	-103.12	-104.18	Dec	105.53
	-34.93	-37.96	-37.96	-37.96	-37.96	-37.96	Jan	37.96
Sesame	-59.97	-63	-63	-63	-63	-63	Jan	63
	-128.93	-131.42	-131.42	-131.42	-131.42	-131.42	Feb	131.42
	-158.07	-161.7	-162.02	-162.34	-162.66	-162.88	Mar	163.15
	-13.2	-23.89	-25.76	-27.64	-29.51	-30.82	April	32.68
Sunflower	-2.57	-5.6	-5.6	-5.6	-5.6	-5.6	Jan	5.6
	-88.73	-91.22	-91.22	-91.22	-91.22	-91.22	Feb	91.22
	-177.63	-181.26	-181.58	-181.9	-182.22	-182.44	Mar	182.71
	-99.47	-110.16	-112.03	-113.91	-115.78	-117.09	April	118.95
Groundnut	-151.33	-165.54	-167.18	-168.8	-170.44	-171.5	Dec	172.85
	-102.37	-105.4	-105.4	-105.4	-105.4	-105.4	Jan	105.4
	-130.59	-133.08	-133.08	-133.08	-133.08	-133.08	Feb	133.08
	-97.48	-101.11	-101.43	-101.75	-102.07	-102.29	Mar	102.56
Copea/	-30.54	-33.57	-33.57	-33.57	-33.57	-33.57	Jan	33.57
Avare/	-94.57	-97.06	-97.06	-97.06	-97.06	-97.06	Feb	97.06
Greengram	-87.73	-91.36	-91.68	-92	-92.32	-92.54	Mar	92.81

Table 12: Surplus and Deficit levels of Crop Water Under Different Probabilities in Koppal district (Kharif)

Crop Kharif	Surplus/Deficit (mm)						Month	Crop water requirement
	Normal	50%	60%	70%	80%	90%		
Rice	-113.84	-140.87	-149.37	-157.85	-166.35	-173.46	June	187.13
	-296.11	-319.36	-328.74	-338.09	-347.47	-355.9	July	375.06
	-303.86	-328.64	-337.58	-346.53	-355.47	-363.18	Aug	379.22
	-238.41	-281.51	-296.81	-312.08	-327.38	-341.12	Sept	372.91
	-242.59	-281.08	-292.68	-304.31	-315.91	-325.45	Oct	344.12
Jowar	-15.71	-42.74	-51.24	-59.72	-68.22	-75.33	June	89
	-92.91	-116.16	-125.54	-134.89	-144.27	-152.7	July	171.86
	-61.24	-86.02	-94.96	-103.91	-112.85	-120.56	Aug	136.6
	108.22	65.12	49.82	34.55	19.25	5.51	Sept	26.28
Maize	48.38	21.35	12.85	4.37	-4.13	-11.24	June	24.91
	-55.52	-78.77	-88.15	-97.5	-106.88	-115.31	July	134.47
	-78.81	-103.59	-112.53	-121.48	-130.42	-138.13	Aug	154.17
	2.43	-40.67	-55.97	-71.24	-86.54	-100.28	Sept	132.07
	76.05	37.56	25.96	14.33	2.73	-6.81	Oct	25.48
Sesame	44.29	17.26	8.76	0.28	-8.22	-15.33	June	29
	-71.07	-94.32	-103.7	-113.05	-122.43	-130.86	July	150.02
	-76.19	-100.97	-109.91	-118.86	-127.8	-135.51	Aug	151.55
	68.4	25.3	10	-5.27	-20.57	-34.31	Sept	66.1
Niger	41.63	14.6	6.1	-2.38	-10.88	-17.99	June	31.66
	-80.41	-103.66	-113.04	-122.39	-131.77	-140.2	July	159.36
	-68.41	-93.19	-102.13	-111.08	-120.02	-127.73	Aug	143.77
	105.39	62.29	46.99	31.72	16.42	2.68	Sept	29.11
Soyabean	-21.66	-48.69	-57.19	-65.67	-74.17	-81.28	June	94.95
	-94.83	-118.08	-127.46	-136.81	-146.19	-154.62	July	173.78
	-47.11	-71.89	-80.83	-89.78	-98.72	-106.43	Aug	122.47
	125.43	82.33	67.03	51.76	36.46	22.72	Sept	9.07
Bajra/ M.millet/ G.nut	45.48	18.45	9.95	1.47	-7.03	-14.14	June	27.81
	-66.91	-90.16	-99.54	-108.89	-118.27	-126.7	July	145.86
	-77.79	-102.57	-111.51	-120.46	-129.4	-137.11	Aug	153.15
	45.34	2.24	-13.06	-28.33	-43.63	-57.37	Sept	89.16
Sunflower	64.59	37.56	29.06	20.58	12.08	4.97	June	8.7
	-45.52	-68.77	-78.15	-87.5	-96.88	-105.31	July	124.47
	-78.81	-103.59	-112.53	-121.48	-130.42	-138.13	Aug	154.17
	39.75	-3.35	-18.65	-33.92	-49.22	-62.96	Sept	94.75
Blackgram	33.59	6.56	-1.94	-10.42	-18.92	-26.03	June	39.7
	-34.81	-58.06	-67.44	-76.79	-86.17	-94.6	July	113.76
	-52	-76.78	-85.72	-94.67	-103.61	-111.32	Aug	127.36
Greengram	23.24	-3.79	-12.29	-20.77	-29.27	-36.38	June	50.05
	-56.73	-79.98	-89.36	-98.71	-108.09	-116.52	July	135.68
	24.3	-0.48	-9.42	-18.37	-27.31	-35.02	Aug	51.06
Horsegram	46.33	19.3	10.8	2.32	-6.18	-13.29	Aug	26.96
	1.78	-21.47	-30.85	-40.2	-49.58	-58.01	Sept	77.17
	-62.97	-87.75	-96.69	-105.64	-114.58	-122.29	Oct	138.33
	28.35	-14.75	-30.05	-45.32	-60.62	-74.36	Nov	106.15
Redgram	53.31	26.28	17.78	9.3	0.8	-6.31	July	19.98
	33.88	10.63	1.25	-8.1	-17.48	-25.91	Aug	45.07
	1.75	-23.03	-31.97	-40.92	-49.86	-57.57	Sept	73.61
	21.77	-21.33	-36.63	-51.9	-67.2	-80.94	Oct	112.73
	-13.97	-52.46	-64.06	-75.69	-87.29	-96.83	Nov	115.5
	-105.21	-124.95	-127.5	-130.06	-132.61	-134.23	Dec	136.23
	-97.19	-109.2	-109.2	-109.2	-109.2	-109.2	Jan	109.2
Copea/ Avare	69.81	42.78	34.28	25.8	17.3	10.19	June	3.48
	24.9	1.65	-7.73	-17.08	-26.46	-34.89	July	54.05
	-33.26	-58.04	-66.98	-75.93	-84.87	-92.58	Aug	108.62
	8.64	-34.46	-49.76	-65.03	-80.33	-94.07	Sept	125.86

Table 13: Surplus and Deficit levels of Crop Water Under Different Probabilities in Koppal district (Rabi/Summer)

Crop Rabi/Summer	Surplus/Deficit (mm) Normal	50%	60%	70%	80%	90%	Month	Crop water requirement
Jowar	117.55	74.45	59.15	43.88	28.58	14.84	Sept	16.95
	-14.23	-52.72	-64.32	-75.95	-87.55	-97.09	Oct	115.76
	-108.59	-128.33	-130.88	-133.44	-135.99	-137.61	Nov	139.61
	-134.74	-146.75	-146.75	-146.75	-146.75	-146.75	Dec	146.75
	-101.8	-103.35	-103.35	-103.35	-103.35	-103.35	Jan	103.35
	-9.54	-10.73	-10.73	-10.73	-10.73	-10.73	Feb	10.73
Maize	79.41	40.92	29.32	17.69	6.09	-3.45	Oct	22.12
	-76.24	-95.98	-98.53	-101.09	-103.64	-105.26	Nov	107.26
	-139.37	-151.38	-151.38	-151.38	-151.38	-151.38	Dec	151.38
	-141.5	-143.05	-143.05	-143.05	-143.05	-143.05	Jan	143.05
	-27.86	-29.05	-29.05	-29.05	-29.05	-29.05	Feb	29.05
Soyabean	9.58	-28.91	-40.51	-52.14	-63.74	-73.28	Oct	91.95
	-110.29	-130.03	-132.58	-135.14	-137.69	-139.31	Nov	141.31
	-108.26	-120.27	-120.27	-120.27	-120.27	-120.27	Dec	120.27
	-8.03	-9.58	-9.58	-9.58	-9.58	-9.58	Jan	9.58
Wheat	76.83	38.34	26.74	15.11	3.51	-6.03	Oct	24.7
	-85.2	-104.94	-107.49	-110.05	-112.6	-114.22	Nov	116.22
	-138.64	-150.65	-150.65	-150.65	-150.65	-150.65	Dec	150.65
	-95.35	-96.9	-96.9	-96.9	-96.9	-96.9	Jan	96.9
Sunflower	68.17	25.07	9.77	-5.5	-20.8	-34.54	Sept	66.33
	-68.29	-106.78	-118.38	-130.01	-141.61	-151.15	Oct	169.82
	-95.59	-115.33	-117.88	-120.44	-122.99	-124.61	Nov	126.61
	-13.56	-25.57	-25.57	-25.57	-25.57	-25.57	Dec	25.57
Safflower	128	84.9	69.6	54.33	39.03	25.29	Sept	6.5
	2.2	-36.29	-47.89	-59.52	-71.12	-80.66	Oct	99.33
	-107.44	-127.18	-129.73	-132.29	-134.84	-136.46	Nov	138.46
	-133.66	-145.67	-145.67	-145.67	-145.67	-145.67	Dec	145.67
	-84.37	-85.92	-85.92	-85.92	-85.92	-85.92	Jan	85.92
Linseed	128	84.9	69.6	54.33	39.03	25.29	Sept	6.5
	2.2	-36.29	-47.89	-59.52	-71.12	-80.66	Oct	99.33
	-107.44	-127.18	-129.73	-132.29	-134.84	-136.46	Nov	138.46
	-133.66	-145.67	-145.67	-145.67	-145.67	-145.67	Dec	145.67
	-84.37	-85.92	-85.92	-85.92	-85.92	-85.92	Jan	85.92
Bengalgram	68.78	30.29	18.69	7.06	-4.54	-14.08	Oct	32.75
	-48.09	-67.83	-70.38	-72.94	-75.49	-77.11	Nov	79.11
	-122.4	-134.41	-134.41	-134.41	-134.41	-134.41	Dec	134.41
	-50.55	-52.1	-52.1	-52.1	-52.1	-52.1	Jan	52.1
Sesame	-84.96	-86.51	-86.51	-86.51	-86.51	-86.51	Jan	86.51
	-179.49	-180.68	-180.68	-180.68	-180.68	-180.68	Feb	180.68
	-197.74	-200.67	-200.67	-200.67	-200.67	-200.67	Mar	200.67
	-10.85	-22.4	-24.93	-27.44	-29.97	-31.87	April	34.96
Sunflower	-6.16	-7.71	-7.71	-7.71	-7.71	-7.71	Jan	7.71
	-130.39	-131.58	-131.58	-131.58	-131.58	-131.58	Feb	131.58
	-218.74	-221.67	-221.67	-221.67	-221.67	-221.67	Mar	221.67
	-90.01	-101.56	-104.09	-106.6	-109.13	-111.03	April	114.12
Groundnut	-8.19	-20.2	-20.2	-20.2	-20.2	-20.2	Dec	20.2
	-143.17	-144.72	-144.72	-144.72	-144.72	-144.72	Jan	144.72
	-181.78	-182.97	-182.97	-182.97	-182.97	-182.97	Feb	182.97
	-123.2	-126.13	-126.13	-126.13	-126.13	-126.13	Mar	126.13
Copea/	-44.55	-46.1	-46.1	-46.1	-46.1	-46.1	Jan	46.1
Avare/	-132.27	-133.46	-133.46	-133.46	-133.46	-133.46	Feb	133.46
Greengram	-111.24	-114.17	-114.17	-114.17	-114.17	-114.17	Mar	114.17

The weekly probability levels were estimated by Weibull plotting positions, 50% probability ranginges from 0 to 31.56mm of rainfall, 60% probability 0 to 26.74mm rainfall, 70% probability 0 to 21.93mm rainfall, 80% probability 0 to17.11mm rainfall, and 90% probability 0 to 12.41mm rainfall.

(b) Koppal

Annual rainfall in Koppal taluk ranges from 351.00mm to 943.00mm. Normal rainfall was estimated for 22 years 592.89mm with standard deviation 150.061mm, coefficient of variation +0.253 and coefficient of asymmetry +0.506. The overall situation of rainfall distribution over the years has been found to be reasonably dependable as probability of occurrence of 75% and 50% normal rainfall were estimated as 93 and 100 per cent respectively.

Rainfall is distributed from April to December with maximum occurring during the months of July, August and September. Weekly rainfall values were used for the statistical distribution. Mean weekly rainfall ranges from 0 to 42.33mm. The most of the rainfall normally occurs between June to October. It can be observed that standard deviation ranges from 6.26 to 45.73, coefficient of variation 0.72 to 2.81 and coefficient of asymmetry 1.44 to 5.62 in all the rainfall weeks. It indicates that the distribution of rainfall is highly scattered and not dependable on weekly basis.

The weekly probability levels were estimated Weibull plotting positions, 50% probability ranges from 0 to 33.01mm of rainfall, 60% probability 0 to 29.39mm rainfall, 70% probability 0 to 23.78mm rainfall, 80% probability 0 to19.16mm rainfall, 90% probability 0 to 14.41mm rainfall.

Rainfall for both the districts follow almost same pattern and reasonably dependable on annual basis. However, it is highly erratic in nature on weekly basis.

In both the study areas (Raichur and Koppal), different probability levels have almost the same ranges of rainfall values inspite of higher rainfall in Raichur district. It indicates homogeneity in pattern of scattering and distribution of rainfall for both the districts. However, exceedence probability of rainfall at different levels namely 50%, 60%, 70%, 80% and 90% are higher in the case of Koppal.

Ranking and weighed transformation distribution relationships were established. The correlation coefficients are ranging from 0.64 to 0.97 in case of Koppal district, whereas it is ranging from 0.58 to 0.98 in the case of Raichur. However, in most of the cases, coefficient of correlation was estimated to be around 90%. Therefore, the established relationship cans be used to find the weekly rainfall corresponding to different percents of exceedence probability.

4.2 Variation of Monthly Rainfall probability and consumptive use Use of Crops

(a) Raichur

Figure 6 represents the monthly variation of rainfall at different probabilities and consumptive use of rice in the kharif season. As can be seen from the figure, even at the status of normal rainfall, there is about 200mm of deficit in rainfall to meet the water requirement of paddy crop. At this present scenario, paddy crop can only be grown in Raichur district with provision of extra irrigation sources.

Figure 7 for represents the monthly variation of rainfall at different probabilities and consumptive use of jowar, maize and bajra in the kharif season. Under normal conditions of mean rainfall, it is just sufficient to meet water requirement the crops (jowar, maize, bajra).

Figure 8 for represents the monthly variation of rainfall at different probabilities and consumptive use of redgram, horsegram and copea in the kharif season. In the present crop calendar for these crops, later part of the cropping period has to be supplemented by irrigation either surface water resources or groundwater resources depending upon the availability. If this alternative is not feasible, crop calendar may have to be shifted to one or two months in advance for these crops..

Figure 9 for represents the monthly variation of rainfall at different probabilities and consumptive use of castor, soyabean and niger in the kharif season. Under normal conditions of mean rainfall, it is just sufficient to meet water requirement of these crops.

Figure 10 for represents the monthly variation of rainfall at different probabilities and consumptive use of groundnut, sesame and sunflower in kharif season. Under normal condition of mean rainfall it is just sufficient to meet all crops. However, for the rainfall below normal mean, then water has to be supplemented by other sources.

Figure 11 for represents the monthly variation of rainfall at different probabilities and consumptive use of blackgram, greengram and avare in the kharif season. Under normal conditions of mean rainfall it is just sufficient to meet water requirements of these crops. In the months of June and July, even 50% of probability rainfall can meet the required crop water requirement for avare and blackgram. However, in the months of August and September, if the rainfall is below 50% probability level, then water has to be supplemented by other sources. In the case of greengram, 50% of rainfall probability can also just meet the water requirement.

Figure 12 for represents the monthly variation of rainfall at different probabilities and variation of consumptive use of jowar, maize and wheat in the rabi season. It can be seen from the figure that under the present crop calendar, it is not possible to grow any of these crops additional application of water from other sources. Initial part of the growing season can be met by rainfall if it is under normal rainfall category. Under such cases, either cropping calendar has to be changed or irrigation water has to be drafted from other sources.

Figure 13 for represents the monthly variation of rainfall at different probabilities and variation of consumptive water requirement for linseed, soyabean, and sunflower in the rabi season. It can be seen from the figure that under the present crop calendar, it is not possible to grow any of these crops without additional application of water from other sources. Initial part of the growing season can be met by rainfall if it is under normal rainfall category. Under such cases, either cropping calendar has to be changed or irrigation water has to be drafted from other sources.

Figure 14 for represents the monthly variation of rainfall at different probabilities and consumptive water requirement for bengalgram in rabi season. It can be seen from the figure that under the present crop calendar, it is not possible to grow the crop without additional application of water from other resources. Initial part of the growing season can be met by rainfall if it is under normal mean rainfall. Under such cases, either cropping calendar has to be changed or irrigation water has to be drafted from other sources.

Figure 15 for represents the monthly variation of rainfall at different probabilities and variation of consumptive water requirement for greengram, groundnut, and sesame in the summer season. It can be seen from the figure that, it is not possible to grow these crops without supplemental irrigation by surface or groundwater resources.

Figure 16 for represents the monthly variation of rainfall at different probabilities and consumptive water requirement for copea and sunflower in the summer season. It can be seen from the figure that, it is also not possible to grow all these crops without supplemental irrigation by surface or groundwater groundwater resources.

(b) Koppal

Figure 17 for represents the monthly variation of rainfall at different probabilities and variation of consumptive water requirement for rice in the kharif season. As can be seen from the figure, even at the status of normal rainfall, there is about 250mm of deficit in rainfall to meet the water requirement of paddy crop. At this present scenario, paddy crop can only be grown in the district with provision of extra irrigation sources.

Figure 18 for represents the monthly variation of rainfall at different probabilities and variation of consumptive use of jowar, maize and bajra in the kharif season. Under normal conditions of mean rainfall, it is not sufficient to meet water requirement of these crops (jowar, maize, bajra). However, if the crop calendar can be shifted by one month later, then the most of the crop water requirement can be met under normal mean rainfall conditions.

Figure 19 for represents the monthly variation of rainfall at different probabilities and variation of consumptive use of redgram, horsegram and copea in the kharif season.

In the present crop calendar for these crops, it is just sufficient to meet the crop water requirement of horsegram and copea. However, for redgram later part of the cropping period needs to be supplemented by either surface water resources or groundwater resources depending up on the availability. Otherwise, crop calendar may be shifted to one or two months in advance than the existing practice.

Figure 20 for represents the monthly variation of rainfall at different probabilities and variation of consumptive use castor, soyabean and niger in the kharif season. Under normal condition of mean rainfall it is not sufficient to meet water requirements of these crops (castor, soyabean, niger). However, if they shift the crop calendar by one month later, the magnitude of water deficit can be reduced under normal rainfall condition. Alternative measures are to be adopted to meet the crop water requirement of these crops.

Figure 21 for represents the monthly variation of rainfall at different probabilities and variation of consumptive water requirement of groundnut, sesame and sunflower in the kharif season. Under normal condition of mean rainfall it is not sufficient to meet water requirements of these crops (groundnut, sesame, sunflower). However, if they shift the crop calendar by one month later, the deficit of crop water requirement can be reduced under normal rainfall condition. Alternative measures are to be adopted to meet the crop water requirement of these crops.

Figure 22 for represents the monthly variation of rainfall at different probabilities and variation of consumptive water requirement of blackgram, greengram and avare in kharif the season. Under normal conditions of mean rainfall, it is just sufficient to meet water requirements, of greengram but not sufficient to meet water requirement of avare and blackgram. However, crop calendar for these crops (avare and blackgram) is sfifted by one by one month later, their crop water requirement can be met under normal rainfall conditions. However it is necessary to take alternative measures to meet the crop water requirements of these crops under the existing crop calendar.

Figure 23 for represents the monthly variation of rainfall at different probabilities and variation of consumptive water requirement of jowar, maize and wheat in the rabi season. It can be seen from the figure that under the present crop calendar, it is not possible to grow any of these crops without additional application of water from other sources. Initial part of the growing season can be met by rainfall if it is under normal rainfall category. Under such cases either cropping calendar has to be changed or irrigation water has to drafted from other sources.

Figure 24 for represents the monthly variation of rainfall at different probabilities and variation of consumptive water requirement of linseed, soyabean, and sunflower in the rabi season. It can be seen from the figure that under the present crop calendar, it is not possible to grow any of these crops without additional application of water from other sources. Initial part of the growing season can be met by rainfall if it is under normal rainfall category. Under such cases either cropping calendar has to be changed or irrigation water has to be drafted from other sources.

Figure 25 for represents the monthly variation of rainfall at different probabilities and variation of consumptive water requirement of bengalgram in the rabi season. It can be seen from the figure that under the present crop calendar, it is not possible to grow the crop without additional application of water from other sources. Initial part of the growing season can be met by rainfall if it is under normal rainfall category. Under such cases, either cropping calendar has to be changed or irrigation water has to be drafted from other sources.

Figure 26 for represents the monthly variation of rainfall at different probabilities and variation of consumptive water requirement of greengram, groundnut, and sesame in the summer season. It can be seen from the figure that, it is not possible to grow these crops without supplemental irrigation by surface water or groundwater resources.

Figure 27 for represents the monthly variation of rainfall at different probabilities and variation of consumptive water requirement of copea and sunflower in the summer season. It can be seen from the figure that, it is also not possible to grow these crops without supplemental irrigation by surface water or groundwater resources.

5.0 Conclusions and Recommendations

The following conclusions and recommendations have been drawn from the study.

1. The annual rainfall distribution over the years are reasonably dependable.
2. The distribution of rainfall is highly scattered in respect of spatial and temporal and not dependable on weekly basis.
3. Nearly 75 to 80 % of the annual rainfall are received during the monsoon season (June to September) associated with temporary dry spells in between causing damages to kharif crops with an average annual rainfall 592 to 732mm. The erratic behavior of monthly rainfall distribution has been observed for both Raichur and Koppal districts. Therefore, it is difficult to develop prediction equations for rainfall. Under such a situation, instead of taking average rainfall

values, models based on probability concept may serve as more useful purpose.

4. The established relationships for Raichur and Koppal districts for different weeks can be used to find the weekly rainfall corresponding to different percents of exceedence probability.
5. Longer periods of daily rainfall data may be used to estimate better consistent probability to make more reasonable crop planning.
6. Tables 14, 15, 16 and 17 show the recommended crop calendar with alternative measures to be taken for better management of water resources. These suggestions are applicable only under normal rainfall condition. However, under 50%, 60%, 70%, 80%, and 90% exceedence probability levels, water requirement of crops need to be supplemented either by groundwater sources or by surface water sources.
7. Paddy crop can not be grown under only rainfed conditions in both Raichur and Koppal districts. Otherwise, about 250mm of irrigation water is additionally required to grow paddy crop in Raichur and Koppal areas.
8. There is a need to change the cropping pattern and crop calendar. Under the existing distribution of rainfall, the recommended cropping pattern for Koppal and Raichur districts are presented in table 18 and 19.
9. Shifting of crop period may not always be suited as there may be overlapping of Kharif, Rabi and summer crops. In such cases, shorter period, high breed variety crops may be adopted.
10. Estimation of weekly crop water requirement is suggested for all principal crops

Table 14: Suggested Crop Calendar for Raichur District (Kharif)

Sl. No.	Crop	Existing		Recommended	
		Crop Period	Total Days	Crop Period	Remarks
1	Paddy	June-Oct	139	June-October	Only under surface and groundwater resources
2	Jowar	June-Sept	107	June-September	Partly may be met by GW/SW
3	Maize	June-Oct	123	June-October	Partly may be met by GW/SW
4	Bajra	June-Sept	108	June-September	Partly may be met by GW/SW
5	Red gram	July-Jan	215	June-December	Later part of cropping period has to be supplemented by other sources
6	Horse gram	Aug-Nov	122	July-October	Under normal condition of rainfall
7	Black gram	June-Aug	92	June-August	Partly to be met by other sources under 50% probability
8	Green gram	June-Aug	76	June-August	Partly to be met by other sources under 50% probability
9	Copea	June-Sept	99	June-September	Under normal condition of rainfall, However, partly to be met by other sources under 50% probability
10	Avare	June-Sept	99	June-September	Under normal condition of rainfall, However, partly to be met by other sources under 50% probability
11	Groundnut	June-Sept	108	June-September	Initial part of cropping period may be by other sources
12	Sesame	June-Sept	103	June-September	Initial part of cropping period may be by other sources
13	Sunflower	June-Sept	99	June-September	Initial part of cropping period may be by other sources
14	Castor	June-Sept	108	June-September	Initial part of cropping period may be by other sources
15	Niger	June-Sept	93	June-September	Initial part of cropping period may be by other sources
16	Soyabean	June-Sept	99	June-September	Initial part of cropping period may be by other sources

Table 15: Suggested Crop Calendar for Koppal District (Kharif)

Sl. No.	Crop	Existing		Recommended	
		Crop Period	Total Days	Crop Period	Remarks
1	Paddy	June-Oct	139	June-October	Only under surface and groundwater resources
2	Jowar	June-Sept	107	July-October	Partly may be met by GW/SW
3	Maize	June-Oct	123	July-November	Partly may be met by GW/SW
4	Bajra	June-Sept	108	July-October	Partly may be met by GW/SW
5	Red gram	July-Jan	215	May-November	Later part of cropping period has to be supplemented by other sources
6	Horsegram	Aug-Nov	122	July-October	Comfortably grow under normal condition of rainfall
7	Black gram	June-Aug	92	July-September	Partly to be met by other sources
8	Green gram	June-Aug	76	June-August	Partly to be met by other sources
9	Copea	June-Sept	99	July-October	Comfortably grow under normal condition of rainfall
10	Avare	June-Sept	99	July-October	Comfortably grow under normal condition of rainfall
11	Groundnut	June-Sept	108	July-October	In addition to some other water resources
12	Sesame	June-Sept	103	July-October	In addition to some other water resources
13	Sunflower	June-Sept	99	July-October	In addition to some other water resources
14	Castor	June-Sept	108	July-October	In addition to some other water resources
15	Niger	June-Sept	93	July-October	In addition to some other water resources
16	Soyabean	June-Sept	99	July-October	In addition to some other water resources

Table 16: Suggested Crop Calendar for Raichur District (Summer/Rabi)

Sl. No.	Crop	Existing		Recommended	
		Crop Period	Total Days	Crop Period	Remarks
1	Jowar	Sept-Feb	145	Aug-Jan	Water requirement will be met under normal condition of rainfall
2	Maize	Oct-Feb	123	Sept-Jan	Water requirement will be met under normal condition of rainfall
3	Wheat	Oct-Jan	108	Sept-Jan	Water requirement will be met under normal condition of rainfall
4	Bengalgram	Oct-Jan	107	Sept-Jan	Water requirement will be met under normal condition of rainfall
5	Green gram	Jan-Mar (S)	80	Jan-Mar (S)	95% of water requirement has to be met by groundwater or other alternative resources
6	Copea/Copea	Jan-Mar (S)	80	Jan-Mar (S)	About 95% of water requirement has to be met by groundwater or other alternative resources
7	Groundnut	Dec-Mar (S)	105	Dec-Mar (S)	About 95% of water requirement has to be met by groundwater or other alternative resources
8	Sesame	Jan-Apr (S)	105	Jan-Apr (S)	About 95% of water requirement has to be met by groundwater or other alternative resources
9	Sunflower	Sept-Dec Jan-Apr (S)	106 96	Sept-Dec Jan-Apr (S)	About 95% of water requirement has to be met by groundwater or other alternative resources
10	Soyabean	Oct-Jan	99	Sept-Dec	Later part of cropping period may be supplemented by other sources
11	Safflower	Sept-Jan	130	Aug-Dec	Later part of cropping period may be supplemented by other sources
12	Linseed	Sept-Jan	130	Aug-Dec	Later part of cropping period may be supplemented by other sources

Table 17: Suggested Crop Calendar for Koppal District (Summer/Rabi).

Sl. No.	Crop	Existing		Recommended	
		Crop Period	Total Days	Crop Period	Remarks
1	Jowar	Sept-Feb	145	Aug-Jan	Some part of water requirement has to be met by other resources
2	Maize	Oct-Feb	123	Sept-Jan	Some part of water requirement has to be met by other resources
3	Wheat	Oct-Jan	108	Sept-Jan	Some part of water requirement has to be met by other resources
4	Bengalgram	Oct-Jan	107	Sept-Jan	Water requirement will be met under normal condition of rainfall
5	Green gram	Jan-Mar (S)	80	Jan-Mar (S)	95% of water requirement has to be met by groundwater or other alternative resources
6	Copea/Avare	Jan-Mar (S)	80	Jan-Mar (S)	About 95% of water requirement has to be met by groundwater or other alternative resources
7	Groundnut	Dec-Mar (S)	105	Dec-Mar (S)	About 95% of water requirement has to be met by groundwater or other alternative resources
8	Sesame	Jan-Apr (S)	105	Jan-Apr (S)	About 95% of water requirement has to be met by groundwater or other alternative resources
9	Sunflower	Sept-Dec Jan-Apr (S)	106 96	Aug-Nov Jan-Apr (S)	About 95% of water requirement is met under normal rainfall condition(Rabi) About 95% of water requirement has to be met by groundwater or other alternative resources(S)
10	Soyabean	Oct-Jan	99	Sept-Dec	Later part of cropping period may be supplemented by other sources
11	Safflower	Sept-Jan	130	Aug-Dec	Later part of cropping period may be supplemented by other sources
12	Linseed	Sept-Jan	130	Aug-Dec	Later part of cropping period may be supplemented by other sources

Table 18: Recommended Crops after Kharif Season Under Raichur District

Sl. No.	Crop	Kharif		Rabi/Summer
		Crop Period	Total Days	Crop
1	Jowar	June-Sept	107	Maize, Wheat, Bengalgram, and Soyabean
2	Maize	June-Oct	123	Groundnut*, Sunflower*, Greengram*, Copea*, Avare*, Sesame*.
3	Bajra	June-Sept	108	Maize, Wheat, Bengalgram,,and Soyabean
4	Red gram	June-Dec	215	Sesame*, Greengram*, Avare*, Copea*, Groundnut*, Sunflower*
5	Horse gram	July-Oct	122	Sesame*, Greengram*, Avare*, Copea*, Groundnut*, Sunflower*
6	Black gram	June-Aug	92	Jowar, Maize, Wheat, Bengalgram, Safflower, Linseed, and Soyabean,
7	Green gram	June-Aug	76	Jowar, Maize, Wheat, Bengalgram, Safflower, Linseed, and Soyabean,
8	Copea	June-Sept	99	Maize, Soyabean, Wheat, and Bengalgram
9	Avare	June-Sept	99	Maize, Soyabean, Wheat, and Bengalgram
10	Groundnut	June-Sept	108	Maize, Soyabean, Wheat, and Bengalgram
11	Sesame	June-Sept	103	Maize, Soyabean, Wheat, and Bengalgram
12	Sunflower	June-Sept	99	Maize, Soyabean, Wheat, and Bengalgram
13	Castor	June-Sept	108	Maize, Soyabean, Wheat, and Bengalgram
14	Niger	June-Sept	93	Maize, Soyabean, Wheat, and Bengalgram
15	Soyabean	June-Sept	99	Maize, Soyabean, Wheat, and Bengalgram

* Summer Crop

Table 19: Recommended Crops after Kharif Season Under Koppal District

Sl. No.	Crop	Kharif		Rabi/Summer
		Crop Period	Total Days	Crop
1	Jowar	July-Oct	107	Groundnut*, Copea*, Avare*, Sesame*, Sunflower*, Greengram*
2	Maize	July-Nov	123	Groundnut*, Copea*, Avare*, Sesame*, Sunflower*, Greengram*
3	Bajra	July-Oct	108	Groundnut*, Copea*, Avare*, Sesame*, Sunflower*, Greengram*
4	Red gram	May-Nov	215	Groundnut*, Copea*, Avare*, Sesame*, Sunflower*, Greengram*
5	Horse gram	July-Oct	122	Groundnut*, Copea*, Avare*, Sesame*, Sunflower*, Greengram*
6	Black gram	July-Sept	92	Maize, Wheat, Sunflower, Bengalgram, and Soyabean
7	Green gram	June-Aug	76	Jower, Maize, Wheat, Sunflower, Bengalgram, Safflower, and Linseed
8	Copea	July-Oct	99	Groundnut*, Copea*, Avare*, Sesame*, Sunflower*, Greengram*
9	Avare	July-Oct	99	Groundnut*, Copea*, Avare*, Sesame*, Sunflower*, Greengram*
10	Groundnut	July-Oct	108	Groundnut*, Copea*, Avare*, Sesame*, Sunflower*, Greengram*
11	Sesame	July-Oct	103	Groundnut*, Copea*, Avare*, Sesame*, Sunflower*, Greengram*
12	Sunflower	July-Oct	99	Groundnut*, Copea*, Avare*, Sesame*, Sunflower*, Greengram*
13	Castor	July-Oct	108	Groundnut*, Copea*, Avare*, Sesame*, Sunflower*, Greengram*
14	Niger	July-Oct	93	Groundnut*, Copea*, Avare*, Sesame*, Sunflower*, Greengram*
15	Soyabean	July-Oct	99	Groundnut*, Copea*, Avare*, Sesame*, Sunflower*, Greengram*

* Summer Crop

as one month is a relatively long period when compared to entire crop growth period. This would provide useful information for evaluating climatic potential for deciding suitable cropping pattern more effectively.

11. In the present expected rainfall distribution, the chances of growing rabi and summer crops in the study areas are not favourable.

12. Water and soil moisture conservation measures are recommended to improve the agricultural practices in Raichur and Koppal districts.

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